Popular Astronomy

Vol. LIII, No. 9 **NOVEMBER, 1945** **Whole No. 529**

John Harrison, a Pioneer in Navigation

By ALFRED GILLGRASS

In these days when navigation plays such an important rôle both on the sea and in the air, we are pleased to have for publication here an account of the early stages of its development. The presentation of this paper may in a small way ascribe credit to him who deserved it because of his perseverance and his genius. EDITOR.

One of the most fascinating pages of English history is that of the 18 century. It was the time when her sailors really established Britain as Mistress of the Seas. Even today we speak of the "Nelson Touch." We remember with pride, the world voyages of Captain Cook and find entertainment in the strange adventures of Captain Bligh of the Bounty, but the man who made the greatest individual contribution to our ad vancement is seldom, if ever, mentioned.

Though he marked the sea with milestones, the name of John Harrison conveys little to us, yet he saved thousands of valuable lives and hundreds of ships and put Britain years ahead of any other Sea Power. He invented and actually made with his own hands, the first successful Marine Chronometer in the world, though he was neither sailor nor clockmaker, but a carpenter and the son of a carpenter, born in an obscure Yorkshire village during the reign of Queen Anne.

The problem was to find a ship's position once she was out of sight of land.

In the early 18th Century, long sea voyages were becoming more common. Ships of all nations were sailing the seven seas, unaware of their exact position. Many were piled up on rocks, rocks supposed to be miles away; the loss of life was appalling. On the run to India—one ship in four never returned—scientists all over the world sought in vain for a solution of the problem. France, Holland, and Spain offered huge rewards but none was claimed. In the year 1714 Britain's Parliament passed an Act, which read "For Providing a Public Reward For Such Person or Persons Who Shall Discover the Longitude at Sea." And that was all. The test was to be a voyage out to the West Indies and the reward Ten Thousand Pounds within One Degree, Fifteen Thousand within Two-Thirds, and Twenty Thousand Pounds within half-a-Degree—which means a time error of two minutes.

A Committee was set up, called the Board of Longitude, which had power to advance small sums.

There were two schools of thought on the problem. Mathematicians

favored a set of tables based on lunar observations, while mechanical men thought in terms of clocks.

Now for the story of John Harrison. He was born at Foulby between Pontefract and Wakefield in 1693. As a bright intelligent lad, he attracted the attention of the parish priest who taught him to read and write—quite an accomplishment for a carpenter's son in those days. Though he became an expert carpenter he was always keen on clocks and when quite a boy he made a clock out of spare wood he had collected, and as a youth of eighteen he made a really fine specimen, almost entirely of wood, which is still kept going at one of the London museums.

Leaving his father's workshop, he travelled round Yorkshire, repairing clocks. They were mostly in church towers and many clergymen helped Harrison with his education. Then one of them told him of the Twenty Thousand Pound reward for the Longitude. John toiled on—repairing clocks by day, studying each evening and dreaming of the £20,000 at night.

He made a careful study of brass and steel, finding them a better medium for clockmaking than wood. He was intrigued with their relative expansions under heat. He invented one of the first compensated pendulums, using rods of brass and steel arranged in such a way as to keep the pendulum a constant length at all temperatures. Known as the "Gridiron," it has been copied and used by clockmakers all over the world for 200 years.

He invented a form of escapement, almost frictionless which never needed oiling. All his spare moments, however, were spent on designing a clock to win the great prize.

A friendly cleric gave him a letter of introduction to Halley, the Astronomer-Royal and a member of the Board of Longitude. So, at the age of twenty-eight, John Harrison set out for London, taking his pendulum, his escapement, and the rough plans for his clock-to-be. The simple Yorkshire carpenter was fully convinced that his feet were already on the ladder of fame. But London did not prove a kindly city for this country lad, with his coarse clothes and still coarser dialect. The Astronomer-Royal was courteous but couldn't understand either Harrison's plans or his accent, and told him that the Board would not advance him a penny at this stage. However, he in turn gave John a letter of introduction to George Graham, another member of the Board, who was at the height of his fame as London's leading clockmaker. As a fellow North-Countryman, Graham gave the Yorkshire lad a warm welcome and understood both his invention and dialect. He advised Harrison to go back home and actually make the clock, and then test it on board some ship before returning with it to London. Finding that Harrison had very little money, he lent him a couple of hundred pounds, without security or interest.

Harrison returned to the North, disillusioned but undismayed. He settled down at Barton-on-Humber, a little village almost opposite Hull. For years he worked night and day, repairing clocks to keep body and soul together, but making his "dream-clock" whenever time permitted. In the finishing stages, he tested it on the Humber barges. The clock was like nothing else on earth. It was made mostly of wood, was very cumbersome and weighed 72 lbs. Every bit of it was his invention and made with his own hands.

Harrison came back to London when he was forty-two years old—this time to stay.

Graham and Halley, the two members of the Board he had seen before, both approved the clock and arranged for a trial to Lisbon on H.M.S. Centurion. The temperature of these parts and the tremendous motion of the ship were a revelation to Harrison. No exact records were kept during the voyage, but returning homeward on H.M.S. Orford, the Captain told him they would soon be sighting Start Point. Harrison said, "Nay ,Captain, according to my clock, it'll noan be t'Start Point, it'll be t'Lizard." And the Lizard it was. The Captain was nearly a degree and a half out of his reckoning, but the clock must have varied only a matter of seconds.

This clock, since called "No. 1," never went to sea again but was kept going at Harrison's house for over thirty years without oil or attention.

The Board of Longitude granted Harrison £500 to continue with his experiments, and in three years he made an improved model, of metal this time, his "No. 2." This clock never went actually to sea as England was at war with Spain at the time. Harrison's third clock took him no less than seventeen years to complete. This unique instrument, consisting of no less than 753 separate parts, worked without any lubrication whatever. Even before it was really finished, it gained the Royal Society's Gold Medal for the best invention of the year 1749.

During this time, assisted by his son, William, Harrison combined all the best ideas of his clock into a much smaller instrument. It was in a silver case, about five inches in diameter, and proved to be the mechanical marvel of the age.

John Harrison entered this for the competition. There were many delays but, at last the trial date was fixed for April, 1761. John Harrison himself was sixty-eight years old by now, and he dared not risk a sea voyage, so he sent his son, William, to Portsmouth with the watch. Here William was kept waiting on one excuse or another until November 18, when he set sail for the West Indies, on H.M.S. Deptford, accompanied by an official referee. Their first port of call on the way was to be Madeira.

On the 10th day out, William suggested to Captain Digge that his ship's course was wrong and that they might miss Madeira altogether. Captain Digge offered to bet William five to one that his watch was

wrong, but he did alter the course and Madeira was sighted next morning.

On reaching Jamaica the watch had only varied a matter of five seconds for the whole trip, or less than one nautical mile—well within the limit of the highest award—and William realized the prize was won.

The harbor-master had instructions to ship William back home on the first boat, but there were no more ships due to leave before spring. Anyhow a few days later, out of the blue, an old, old ship came sailing into harbor. She was the Sloop-of-War Merlin. Her sails were tattered, her timbers strained, and she presented a sorry spectacle. She had been condemned as unseaworthy and was making her last voyage home to the ship-breakers.

William was sent aboard and they set sail for England. They had a terrible passage and were nearly six weeks without an inch of dry deck.

William wrapped a blanket round his precious watchbox and when this was saturated, would wring it out by hand and apply another one. His only method of drying the blankets was by wrapping them around his body when snatching an occasional sleep.

However, William wound the watch each day in the presence of Captain Bourke and they sailed into Spithead on March 25. The voyage took over five months and the total error of the watch in all that time was well under two minutes.

The Board of Longitude was astounded with the results. They declared they must be accidental and refused to pay until another trial had been made. After much discussion, they advanced Harrison £2,500, so he agreed to a further trial. This was not arranged until two years later, when William set sail on the Man-of-War Tartar. The official referee was Mr. Nevil Maskelyne, Chairman of the Board, and soon to become Astronomer-Royal. Maskelyne, by the way, did not favor a watch at all, but preferred his own lunar tables. The watch gained only 38.4 seconds for the seven weeks' trip. William returned triumphant a few days later.

King George III, a keen student of horology, received John Harrison and his son in audience and congratulated the old man on his great achievement. Then the simple, trusting Yorkshireman went to the Board of Longitude to draw his £20,000.

Although the prize was won, the Board refused to make any payment whatever until John had disclosed the secret of his watch to a Committee of three watchmakers, and handed over to the Board, in trust for the Public, all four of his time-pieces. John lost his temper, and said some very rude things and left the building.

Finally John had to give way. He met the experts and showed them the secrets of his master-piece. They were amazed that a self-taught rustic should have conceived such an instrument. One of the Board, Larcom Kendall, took all Harrison's plans and arranged to make a

replica, which took three years to complete. Harrison had to surrender his three clocks before he got the balance of half his just reward.

He was determined to get the other £10,000 due to him. So he made another watch and petitioned King George to have it tested. The King tested this personally, meeting William Harrison every morning at Kew Observatory. Its total error in ten weeks was only 4½ seconds. The King reported this test to the Board and recommended payment, but this request too was ignored. George III again received the Harrisons in audience, listened to the old man's pitiful tale and was heard to murmur, "These people have been cruelly wronged," then, losing his temper, he cried, "Harrison I'll see you righted" . . . Harrison petitioned Parliament and the Board was ordered to pay, and John got the remainder of the reward when he was eighty years old.

Harrison's watch never went to sea again, but the replica made by Kendall was lent to Captain Cook, who put it in charge of his navigating officer, Captain Bligh, on the Second World Voyage. Later Captain Bligh took it on his famous voyage on the "Bounty" and it was stolen by the mutineers.

Harrison's instruments however, were roughly treated by the Astronomer-Royal and dumped in the cellars of Greenwich Observatory. They mouldered there for over 150 years.

In 1923 a retired British Naval Officer, Lt. Cmdr. R. T. Gould, was so impressed with Harrison's work that he could not bear to see his obsolete instruments in a state of decay. At his own expense he spent no less than twelve years renovating them. In 1935 he gave a lecture at the Drapers' Hall, London with all the time-pieces going in front of him. . . No statue has been erected to the memory of John Harrison. Yet he has his memorial. Every navigating officer as he enters up his log unwittingly adds a line to the epitaph of a great benefactor.

Concerning Our Nearer Celestial Neighbors

By L. V. ROBINSON

As terrestrial environments have now widened to a point where no group is beyond the gaze of all the others, so has the celestial environment of puny man likewise expanded to such an extent that he can, in a certain sense and with some confidence of success, begin to meddle in the affairs of his spatial neighbors. Inasmuch as he can now sketch the general features of a star by knowing its parallax, its apparent magnitude, and its spectrum, lurking somewhere in the mind then may be the inquisitiveness to know something as to the nature of an "average" star.

But no one who has devoted any serious study to the stars would at-

tempt to make any inferences as to the general nature of an "average" star from those visible to the naked eye: about 55 light years would be the limit of naked-eye visibility of a star no brighter than the sun, and 5.5 light years would be the limit for a star with the intrinsic brightness just one-hundredth of that of the sun. Hence, inasmuch as a few stars are known with absolute brightnesses less than one ten-thousandth of that of the sun, it becomes apparent that these most unobtrusive neighbors of the sun must make their presence known through other means than inherent brightness. Without some way of exhibiting their proximity, these stars cannot dissociate themselves from the thousands of others which owe their apparent faintness to distance rather than to low light-giving power.

Except through its proper motion, a star of very low candle power is then without effective means of attracting the attention of the casual observer; and, over relatively short intervals of time, even high proper motion hardly suffices. To the more assiduous and more experienced observer, the alternative is a closer study of spectral lines; and here is a great field for the astronomer, or astronomers, who can develop the means of quickly distinguishing between great multitudes of dwarfs and giants from spectrum plates taken with an objective prism spectrograph, say, after the manner of the Henry Draper Catalogue. Since as yet this ambition has not been adequately realized, it is not difficult to understand why the evidence now available suggests that only about half of the sun's nearest neighbors, within about 30 light years, have thus far been discovered.

It is obvious, however, that the only way to learn anything of the "average" star is to undertake an intensive survey of the stars in the immediate neighborhood of the sun, keeping in mind two great difficulties that challenge the realization of this aim. There is, in the first place, the fact just pointed out, that many of the intrinsically faint stars are necessarily omitted from such a statistical study because their proximity has not been suspected. In the second, there is no assurance whatever that the stars in the immediate neighborhood of the sun are in every way representative of the whole Milky Way system. Even assuming all the data to be available and the stars to be representative, the question then arises as to the meaning of an "average" star. Perhaps the safer plan is to present only the data, keeping in mind all the sources of error, some of them perhaps systematic, and leave the reader to infer what the "average" star is like.

Although some parallaxes have since been published that would modify to some extent the data and selections made here of the stars nearest the sun, the list published by Kuiper (*Ap. J.*, **95**, 201, 1942) appears to be sufficient for the purposes here intended. For the sake of convenience, however, and although the data mentioned in the next paragraph have been computed for all the 254 stars belonging to Kui-

per's list, only those relating to the sixty nearest stars have been entered in Table II. Moreover, in referring to a star in future discussions, the numbering is in order of distance from the sun, and not according to that of Kuiper. Kuiper's list included all stars then known with parallaxes greater than 0".094 and extending to a distance of 34.4 light years from the sun.

Although in most cases *individual* results appear to be significant, even for these no high degree of accuracy is claimed. Of more importance are the *general* results relating to such physical characteristics as: a) luminosity, b) diameter, c) mass, d) density, e) gravitational attraction, and f) velocity of escape. For the first four of these items, the sun is taken as the standard of comparison; for e), the fifth of these, the unit is the gravitational attraction of the earth; and for f), the entries are made in miles per second. Perhaps, then, some notions as to the general characteristics of the "average" star may be gained by weighing these data, as they appear in Table II, and by making appropriate comparisons with the sun.

Assuming the parallax and visual magnitude of a star to be accurately known, its luminosity, in the terms of the sun, say, is then likewise precisely known—in fact, more precisely than any of the other attributes computed in Table II. The only remaining source of error in calculating the luminosity of the star is the visual magnitude of the sun; and the value of —26.72, perhaps most frequently assumed, is probably not seriously in error.

TABLE I

PROVISIONAL DATA FOR COMPUTING THE DIAMETERS OF MAIN-SEQUENCE STARS

Sp.	Log T	A_T	Sp.	Log T	A_T
B5	4.130	0.340	G5	3.735	0.987
A0	4.014	0.477	K0	3.694	1.088
A5	3.934	0.593	K5	3.616	1.317
F0	3.869	0.705	M0	3.534	1.599
F5	3.819	0.800	M5	3.451	1.932
G0	3.775	0.893	N	3.366	2.351

The computed diameter of a star, however, is less accurate, since it must depend upon two further assumptions: first, that the observed spectral type is a true measure of the effective temperature of the star and, secondly, that the star radiates as a black body. Interferometer measurements of diameters made at Mount Wilson suggest that computations based upon absolute magnitude and spectral type are rather precise. Assuming then that a star radiates as a black body and that the diameter D can be computed by the formula,

$$\log D + 0.2\, M_b + 2 \log T = C,$$

where M_b is the absolute bolometric magnitude, T the effective temperature estimated from spectral type, and C a constant to be determined from the corresponding data for the sun, it appears that the diameters thus computed are not greatly in error.

TABLE II

No.	Star	1900 Position h m	° ′	Visual Mag. m	Sp.	Parallax	Abs. Mag. M	Luminosity	Distance in L. Y.	Mass	Diameter	Density	Vel. of Escape	Gravity
	Sun	.....	—26.72		G0	206265″	4.85	1.0	.....	1.00	1.000	1.00	384	28.0
1	Prox. Centauri	14 22.8	—62 15	11.3	m	0″.762	15.7	0.000046	4.28	0.10	0.029	4.0×10^3	697	3220
2	α Centauri A	14 32.8	—60 25	0.33	G4	.756	4.72	1.13	4.31	1.14	0.953	1.32	421	35.2
3	α Centauri B	14 32.8	—60 25	1.70	K1	.756	6.09	0.319	4.31	0.97	0.818	1.77	419	40.5
4	BD+4° 3561	17 52.9	+ 4 25	9.46	M5+	.543	13.13	0.000488	6.00	0.20	0.220	19.0	368	117
5	Wolf 359	10 51.6	+ 7 36	13.5	M8	.403	16.5	0.000022	8.08	0.11	0.072	290	471	581
6	BD+36° 2147	10 57.9	+36 38	7.47	M2+	.388	10.41	0.00597	8.40	0.32	0.463	32.7	322	42.3
7	Sirius A	6 40.7	—16 35	—1.52	A1	.376	1.36	24.9	8.66	2.45	1.69	0.51	462	24.0
8	Sirius B	6 40.7	—16 35	8.54	A5	.376	11.42	0.00236	8.66	0.85	0.021	9.3×10^4	2450	5.44×10^4
9	Ross 154	18 43.6	—23 56	10.5	M5+	.350	13.2	0.000457	9.31	0.20	0.213	20.5	370	122
10	L 789-6	22 33.0	—15 52	12.3	M6+	.328	14.9	0.000096	9.93	0.14	0.116	92.5	427	299
11	Ross 248	23 37.0	+43 39	12.2	M6+	.314	14.7	0.000115	10.37	0.15	0.127	73.1	417	259
12	ε Eridani	3 28.2	— 9 48	3.75	K2	.303	6.16	0.299	10.75	0.68	0.879	0.99	336	24.4
13	ι Ceti	1 39.4	—16 28	3.66	G5	.298	6.03	0.337	10.93	0.66	0.603	3.03	403	51.0
14	61 Cygni A	21 02.4	+38 15	5.35	K3	.296	7.71	0.0718	11.01	0.47	0.479	4.30	381	57.5
15	61 Cygni B	21 02.4	+38 15	6.05	K5	.296	8.41	0.0377	11.01	0.41	0.432	5.13	377	61.9
16	Procyon A	7 34.1	+ 5 29	0.53	F4	.291	2.85	6.31	11.20	1.48	1.66	0.32	363	15.0
17	Procyon B	7 34.1	+ 5 29	10.8	..	.291	13.1	0.000501	11.20	0.46	0.095	540	847	1430
18	ε Indi	21 55.8	—57 12	4.70	K5	.288	7.00	0.138	11.31	0.58	0.828	1.02	322	23.7
19	BD+43° 44 A	0 12.7	+43 27	8.1	M2	.284	10.4	0.00603	11.47	0.32	0.442	3.67	325	45.4
20	BD+43° 44 B	0 12.7	+43 27	10.9	M5+	.284	13.2	0.000457	11.47	0.20	0.213	20.5	370	122
21	BD+59° 1915 A	18 41.7	+59 29	8.92	M3+	.282	11.17	0.00296	11.56	0.28	0.391	4.76	328	52.1
22	BD+59° 1915 B	18 41.7	+59 29	9.73	M4	.282	11.98	0.00141	11.56	0.24	0.292	9.73	350	79.4
23	CD—36° 15693	22 59.4	—36 26	7.23	M0+	.278	9.45	0.0144	11.72	0.38	0.547	2.30	319	35.2
24	CD—45° 1841	5 07.7	—44 59	8.8	M0	.262	10.9	0.00380	12.44	0.27	0.261	14.9	388	109
25	BD+5° 1668	7 22.0	+ 5 32	10.0	M4+	.262	12.1	0.00126	12.44	0.24	0.299	9.02	345	75.5
26	Ross 614	6 24.3	— 2 44	11.3	M6+	.260	13.4	0.000380	12.53	0.20	0.231	16.1	356	104
27	CD—39° 14192	21 11.4	—39 15	6.65	M0	.257	8.70	0.0288	12.67	0.44	0.719	1.19	301	23.9
28	Krüger 60 A	22 24.4	+57 12	9.87	M4	.256	11.91	0.00150	12.72	0.25	0.301	9.44	356	77.1
29	Krüger 60 B	22 24.4	+57 12	11.3	M6	.256	13.3	0.000417	12.72	0.14	0.221	12.9	306	80.0
30	BD—12° 4523	16 24.7	—12 25	9.8	M4	.255	11.8	0.00166	12.78	0.25	0.317	7.94	344	70.5
31	Ross 42	5 26.7	+ 9 45	11.4	M6	.250	13.4	0.000380	13.03	0.19	0.211	20.5	368	121
32	van Maanan 2	0 43.9	+ 4 55	12.4	G	.243	14.3	0.000166	13.40	(0.60)	0.0114	4.0×10^5	2790	1.28×10^5
33	Ross 128	11 42.6	+ 1 23	11.0	M5+	.230	12.8	0.000661	14.16	0.22	0.256	12.9	353	92.5
34	Ross 882	7 39.4	+ 3 48	11.6	M6	.230	13.4	0.000380	14.2	0.19	0.211	20.5	368	121
35	Wolf 424 A	12 28.4	+ 9 34	12.7	M7	.225	14.5	0.000138	14.5	0.16	0.152	45.7	394	194
36	Wolf 424 B	12 28.4	+ 9 34	12.7	M7	.225	14.5	0.000138	14.5	0.16	0.152	45.7	394	194

33	Ross 128	11	42.6	+ 1	23	11.0	M5+	.230	12.8	0.000061	14.16	0.22	0.256	12.9	333	92.3
34	Ross 882	7	39.4	+ 3	48	11.6	M6	.230	13.4	0.000380	14.2	0.19	0.211	20.5	368	121
35	Wolf 424 A	12	28.4	+ 9	34	12.7	M7	.225	14.5	0.000138	14.5	0.16	0.152	45.7	394	194
36	Wolf 424 B	12	28.4	+ 9	34	12.7	M7	.225	14.5	0.000138	14.5	0.16	0.152	45.7	394	194
37	CD—46° 11540	17	21.1	— 46	47	9.7	M3+	.225	11.5	0.00219	14.5	0.26	0.336	6.97	341	65.5
38	CD—37° 15492	23	59.5	— 37	51	8.57	M3	.222	10.30	0.00661	14.7	0.34	0.540	2.16	306	32.7
39	BD+50° 1725	10	05.3	+ 49	58	6.54	K8	.220	8.25	0.0437	14.8	0.46	0.673	1.50	317	28.6
40	BD—15° 6290	22	47.9	— 14	47	10.27	M5	.220	11.98	0.00141	14.8	0.25	0.344	6.21	329	59.7
41	BD+68° 946	17	37.0	+ 68	26	9.13	M3+	.213	10.77	0.00429	15.3	0.31	0.470	3.00	313	39.4
42	CD—44° 11909	17	29.8	— 44	14	10.9	M5	.208	12.5	0.000871	15.7	0.23	0.270	11.4	352	86.5
43	α Aquilae	19	45.9	+ 8	36	0.91	A5	.208	2.50	8.71	15.7	1.71	1.236	0.91	453	31.4
44	BD+43° 4305	22	42.5	+ 43	49	10.25	M5	.207	11.83	0.00161	15.7	0.26	0.368	5.22	324	53.8
45	CD—49° 13515	21	26.9	— 49	26	8.9	M3	.207	10.5	0.00550	15.7	0.32	0.492	2.72	312	37.4
46	40 Eridani A	4	10.7	— 7	49	4.52	K1	.202	6.05	0.331	16.1	0.68	0.834	1.18	348	27.5
47	40 Eridani B	4	10.7	— 7	49	9.62	A	.202	11.15	0.00302	16.1	0.45	0.0237	3.4×10^4	1680	2.25×10^4
48	40 Eridani C	4	10.7	— 7	49	11.1	M6	.202	12.6	0.000794	16.1	0.20	0.306	7.02	311	60.0
49	AC 79°3888	11	41.3	+ 79	14	11.0	M4+	.201	12.5	0.000871	16.2	0.22	0.249	14.3	362	99.8
50	CD—32° 16135 A	20	35.6	— 32	47	10.9	M5	.200	12.4	0.000955	16.3	0.23	0.283	10.2	348	80.5
51	CD—32° 16135 B	20	35.6	— 32	47	11.1	M5+	.200	12.6	0.000794	16.3	0.23	0.281	10.2	344	80.0
52	70 Ophiuchi A	18	00.4	+ 2	31	4.19	K1	.196	5.65	0.479	16.6	0.90	1.002	0.89	365	25.1
53	70 Ophiuchi B	18	00.4	+ 2	31	5.87	K5	.196	7.33	0.102	16.6	0.73	0.711	2.03	389	40.4
54	BD+20° 2465	10	14.2	+ 20	22	9.46	M5	.193	10.89	0.00384	16.9	0.32	0.568	1.76	290	28.0
55	I (UC37)	11	40.5	— 64	17	12.5*	b	.193	13.9*	0.00024	16.9	(0.60)	0.0034	1.5×10^7	321	7.6×10^5
56	BD+15° 2620	13	40.7	+ 15	26	8.58	M1+	.191	9.99	0.00879	17.1	0.34	0.494	2.85	321	39.5
57	BD—21° 1377	6	06.4	— 21	49	8.2	M0	.183	9.5	0.0138	17.8	0.37	0.405	2.78	259	62.8
58	L 347-14	19	13.4	— 45	42	13.4*	m	.182	14.7*	0.000115	17.9	0.12	0.0454	1250	617	1580
59	η Cassiopeiae A	0	43.0	+ 57	17	3.60	G0	.182	4.90	0.955	17.9	0.72	0.818	1.31	361	30.1
60	η Cassiopeiae B	0	43.0	+ 57	17	7.34	K6	.182	8.64	0.0305	17.9	0.46	0.438	5.50	395	67.3

Remarks

1, c.p.m. with α Centauri. 2, 3, Separation, 17″65; period, 80.09 years. See Table III. 4, Barnard's Star. See Table III. 5, See Table III. 6, Lal 21185. See Table III. 7, 8, Separation, 7″57; period, 49.94 years. See Table III. 12, See Table III. 13, See Table III. 14, 15, Separation, 15″ to 26″; very long period. See Table III. 16, 17, Separation, 4″26; period, 40.23 years. Assumed spectrum for B is M0. See Table III. 18, See Table III. 19, 20, Groombridge 34; separation, 38″. See Table III. 21, 22, Separation, 12″ to 17″. See Table III. 23, See Table III. 24, Kapteyn's star. See Table III. 25, See Table III. 26, Has a dark companion? 27, Lac 8760. See Table III. 28, 29, Separation, 2″36; period, 44.52 years. See Table III. 32, See Tables III and IV. 35, 36, Separation, 1″; rapid motion. 38, See Table III. 39, Groombridge 1618. See Table III. 40, Ross 780. 41, See Table III. 43, See Table III. 44, See Table III. 46, 47, 48, Separation of AB, 83″; of BC, 6″89, with period 248 years. See Tables III and IV. 50, B is 3″ removed, both c.p.m. with No. 77. See Table III. 52, 53, Separation, 4″56; period, 87.85 years. See Table III. 54, See Table III. 55, Sp. B5, assumed. See Table IV. 56, See Table III. 58, Sp. assumed, K7. 59, 60, See Table III. Period, 526 years; separation, 12″53.

The above equation assumes, of course, that it is possible to determine M_b from the absolute visual magnitude M_v and the spectral type. Again a good approximation to the truth appears to be within reach through the Hertzsprung formula,

$$M_b = M_v - 2.3\ (14{,}300°/T)^{0.93} - 10 \log T + 42.92.$$

Then, since $M_b - M_v$ is a function of temperature only, it is convenient to write

$$\log D + 0.2\ M_v = C - 2\ [\log T + 0.1\ (M_b - M_v)] = A_T,$$

where A_T is likewise a function of temperature only. Hence, a provisional relationship, as in Table I, is established between A_T and spectral type, assuming the value of C to be known; and the diameter of a star is quickly calculated by the formula,

$$\log D = A_T - 0.2\ M_v.$$

Table I assumes for the sun

$$M_v = 4.85,\ T = 5520°,\ C = 8.441.$$

The value of A_T corresponding to a G0 star, like the sun, does not give $D = 1$ for the sun for the reason that the temperature of the average star of spectral type G0 and belonging to the main sequence has been assumed higher than that of the sun or, assuming temperature to be the sole criterion, that the spectral type of the sun is really later than G0. For the giant stars, adjustments are necessary for Table I, since for the most part giants of spectral type later than F0 are cooler than stars of the main sequence with the same spectral type. As Figure 1 in Kuiper's paper already referred to shows, the stars not belonging to the main sequence are so few that it is hardly worth while to add anything more to Table I. Although the few photographic magnitudes—indicated by a star after the magnitude in Table II—given by Kuiper have been kept, they were, of course, reduced to visual magnitudes, by subtracting color index in all computations, except luminosity, involving them.

The bolometric magnitude M_b cannot be entirely overlooked, as the above formula for log D might suggest, because of the fact that it enters into the mass-luminosity relation. Except for the binary and triple systems where the masses are otherwise known, the entries in Table II have been computed by the equation,

$$m = 1.68\ (e^{-0.4\ M_b} + e^{-0.2\ M_b}),$$

which appears to represent the mass-luminosity relation as conveniently as possible and without any noticeable systematic error. For the 25 members of multiple systems for which the spectra are known and not belonging to the white-dwarf sequence, the average deviation from the above equation corresponds to 18 per cent of the observed masses. Some of this deviation may, of course, be attributed to accidental errors in the observed data.

The mass m and the diameter D can now be used to calculate the density ρ, the gravitational attraction g, and the velocity of escape v. The necessary equations are:

$$\rho = m/D^3,$$
$$g = 28\,(m/D^2),$$
$$v = 384\,\sqrt{(m/D)}.$$

Although ρ, g, and v are admittedly less accurate than any of the preceding data, it seems perhaps significant that there is so little variation among the calculated values of v entering into Table II.

In this connection, it should be pointed out that inasmuch as the mass-luminosity relation cannot be applied to stars belonging to the class of white-dwarfs, some assumption must be made as to their masses. For two of the seven of these stars listed in Table IV, the masses presumably are known from the usual binary star data. These two stars are Sirius B and 40 Eridani B for which the observed values, in terms of the sun's mass, are 0.85 and 0.45, respectively. The others are assumed therefore, perhaps with no great error, to be 0.60 and ρ, g, and v computed accordingly.

TABLE III

No.	Space Velocity	Distance—Present	Distance—Nearest	Time Interval	No.	Space Velocity	Distance—Present	Distance—Nearest	Time Interval
2	19.8	4.3	3.1	+ 28,000	27	42.1	12.7	12.1	— 18,500
4	88.1	6.0	3.8	+ 9,900	28	18.2	12.7	7.2	+107,000
5	65.8	8.1	4.3	+ 19,500	32	152	13.4	3.2	— 16,000
6	65.2	8.4	4.7	+ 19,900	38	82.5	14.7	14.5	— 6,000
7	11.5	8.7	7.8	+ 61,000	39	25.7	14.8	11.2	+ 70,000
12	13.3	10.7	7.7	—105,000	41	21.0	15.3	13.2	+ 69,000
13	21.4	10.9	9.7	+ 44,000	43	18.7	15.7	7.8	+135,000
14	68.9	11.0	8.3	+ 17,000	44	12.2	15.7	15.6	— 23,600
16	12.9	11.2	11.1	+ 23,000	46	65.0	16.1	14.8	+ 18,600
18	54.1	11.3	10.0	+ 18,000	50	7.3	16.3	14.8	—177,000
19	30.5	11.5	11.3	— 11,500	52	17.5	16.6	16.2	+ 44,000
21	23.8	11.6	11.6	now	54	9.4	16.9	13.5	—200,000
23	73.4	11.7	11.7	— 2,500	56	36.7	17.1	16.5	— 22,000
24	180.0	12.4	6.8	— 11,000	59	20.5	17.9	17.3	— 44,500
25	44.4	12.4	11.8	— 16,000					

Table III contains the space velocity, in miles per second, the present distance, and the distance at nearest approach to the sun for all the stars in Table II for which the proper motions and radial velocities are known. The other data are not given, since they can be obtained from Kuiper's paper or from other sources. A plus sign before the *time of nearest approach* indicates that such is to occur in the future; and a minus sign indicates that that star has already, by the given number of years, passed its nearest approach and that it is now receding from the solar system. The present distance of the star is repeated from Table II only for the sake of comparison.

Among these nearer neighbors of the sun, there are also some stars

that, for historical reasons, are worthy of comment. First among these to be mentioned perhaps is α Centauri, the first star for which a parallax was sought and, for more than 75 years, the nearest star known. As early as 1689, when the fact was observed by Richaud at Pondicherry, in India, it was known that α Centauri was really a double star. This was one line of evidence, together with its apparent brightness and rather high proper motion, that might suggest—after it became generally recognized that the two stars really are physically connected and that they revolve about a common center of gravity—that here was one of the near neighbors of the sun. Thus, at the Cape of Good Hope, Thomas Henderson, in 1832, began a series of observations to determine a parallax. Observing with a meridian circle, however, Henderson found his task somewhat long and tedious; and not until January 3, 1839, was he able to announce a parallax. The value found by him was about 1″ of arc, whereas the actual value is very near 0″.756.

The components of α Centauri are separated by a distance of about 2,200,000,000 miles, or by a little more than the distance of Uranus from the sun.

Proxima Centauri, discovered by Innes in 1915, is slightly more than two degrees removed from the two components of α and probably represents a third member of the system. If so, then at least 700,000 years are required for it to make a complete revolution around the other two brighter members which revolve about their center of gravity in 80 years.

The honor of being the first star for which a parallax was announced, however, belongs to 61 Cygni. The duplicity of this faint pair, numbered 14 and 15 in Table II, had been noticed by James Bradley in 1753. In reducing the star positions measured by Bradley, F. W. Bessel, who in 1810 had been called to the directorship of the new observatory being erected at Königsberg, observed in 1812 the common proper motion of the two stars. Ten years later, Sir John Herschel, in reviewing the observations made on the two stars up to that time, affirmed that they really constituted a binary system and further suggested that here was "a fit object for the investigation of parallax." Some years later, Bessel secured for the new observatory at Königsberg a heliometer devised by Joseph Fraunhofer, and decided to seek the parallax of 61 Cygni. Bessel's decision bore fruit; and, in December, 1838, he was able to announce a parallax of about one-third of a second, comparing very favorably with the present, and quite accurate, value of 0″.296.

C. F. W. Peters, at Pulkova, was the first to announce a period for the system of 61 Cygni. He gave a value of about 783 years as required for the two stars to revolve about a common center of gravity. At the present time, the period still is not accurately known; but the evidence suggests a value of around 700 years and that the mean distance between the two stars therefore must be more than twice that of Pluto from the sun.

Bessel also discovered, in 1834, that the proper motion of Sirius is not uniform. Indeed, it later appeared that the path was wavy; and, in 1844, he was prompted to announce his final conclusion that Sirius must have a darker companion to account for this observed phenomenon, the first of its kind known in the history of astronomy. In 1862, Alvin Clark, at Cambridgeport, Mass., was testing a telescope, intended for the University of Mississippi but later acquired by Dearborn Observatory at Northwestern University, and chanced to direct it on Sirius. Thus, almost twenty years after Bessel had made his prediction, Clark became the first to see the famous companion of Sirius. The star acquired further notoriety in 1925 when Adams, in making a test of the theory of relativity at Mount Wilson, announced that his study of the spectrum of Sirius B confirmed the prevalent suspicion that the star undoubtedly was of very high density. This is shown in Table IV.

Vega was another star to catch the attention of early parallax hunters. In fact, Wilhelm Struve began his observations on this star more than a year before Bessel started his investigations for the parallax of 61 Cygni and completed them about the same time as Bessel. Vega, here recognized as No. 150 in order of distance from the sun, proves to be also the brightest star within 34.3 light years of the sun. In obtaining a parallax of 0″.25 for Vega, Struve set its distance at about 13 light years, whereas its distance is now known to be 26.9 light years. No less than 51 stars like our sun would be required to give as much light, viewed from the same distance, as Vega.

The faintest star appearing in Kuiper's list is numbered 92 in distance from the sun. Since the parallax is not accurately known, however, the star may be considerably brighter than this value of the parallax would indicate. If this value is correct, then no less than 310,000 stars with its luminosity, placed at the sun's distance from the earth, would be required to send the earth as much light as the sun. That is to say, if the earth had this star, L 68-29, as its sun at a distance of 93,000,000 miles, the mean temperature on the earth would stand more than 400 below zero, on the Fahrenheit scale.

The star with the greatest diameter—and also made of the most rarefied material—appears to be β Geminorum, or Pollux. The computed diameter of Pollux—No. 218 in the list—is 10.1 times that of the sun, or about 8,700,000 miles. The density, quite large as compared to some of the much more distant red giants, appears to be but 0.0023 of the sun's density, or about 0.0032 times the corresponding volume of water. The gravitational attraction is likewise small, just 70 per cent of the earth's attraction.

Assuming all the data to be correct, the star with the smallest diameter, the greatest density, and the greatest gravitational attraction is I (UC 37), or No. 55 in Table II. It must be confessed, however, that the values listed for these physical characteristics also may be consider-

ably in error due to the fact that both the spectral type and the mass probably are more uncertain than usually. If the data are approximately correct, the diameter of this star is but 3,000 miles, hardly fifty per cent greater than the moon's diameter; and, as Table IV shows, its density is therefore about 15,000,000 times that of the sun, the average quart of material weighing nearly 22,000 tons! For the gravitational attraction, accordingly, these data give an enormous value of 1,400,000 times that of the earth. Assuming this value to be correct and that it were possible for a man weighing 150 pounds on the earth to be weighed by a spring balance on the star, a simple calculation therefore shows that the man would weigh more than 10,000 tons on the star. To escape from the star, he apparently would have to attain the enormous velocity of more than 5,000 miles per second—a figure also the greatest in the "velocity of escape" column.

The speed demon of Kuiper's list is No. 197, or Groombridge 1830. This star, just beyond the limit of naked-eye visibility for the average eye, was shown by Argelander, in 1842, to be moving across the sky by an amount equal to the diameter of a full moon in about 265 years: that is, could its proper motion remain constant at its present value, Groombridge 1830 would move around the celestial sphere in about 184,000 years. This cross velocity, now viewed from a distance of 30.2 light years, corresponds to 192 miles per second. Since it is also approaching the earth with a velocity of 61 miles per second, the star is therefore moving through space with the terrific speed of about 201 miles per second. After about 84,000 years, however, the motion of Groombridge 1830 toward the sun will cease; and, then at a distance of 29.3 light years it will begin slowly to recede.

In annual proper motion, however, Groombridge 1830 is exceeded by Barnard's star, or No. 4 in Table II. Inasmuch as the latter is but six light years away, its cross-motion is only 56 miles per second. A velocity toward the earth of 68 miles per second therefore gives it a space motion of only 88 miles per second.

Apparently no star in the list will ever approach nearer the sun and the earth than the system of α Centauri, including presumably Proxima. These three stars, as Table III indicates, will in some 28,000 years approach within about 3.1 light years of the earth and sun and then begin

TABLE IV

THE NEARER WHITE-DWARFS

Star	Spect.	Mass	Diameter in Miles	Wght. of 1 qt. of Material
Sirus B	A5	0.85	18,070	137 tons
van Maanan 2	(G0)	(0.60)	9,900	592 tons
40 Eridani B	(A5)	0.45	20,500	50 tons
I (UC 37)	(B5)	(0.60)	2,970	21,800 tons
L 745-46	(F0)	(0.60)	6,440	2,140 tons
L 97-12	(F5)	(0.60)	4,440	6,550 tons
Wolf 489	(G8)	(0.60)	9,700	625 tons

to recede. Due to the mutual attractions within the system, as yet it cannot be predicted that Proxima will then approach nearer than the other two. Some 16,000 years ago, however, van Maanan's star—No. 32 in Table II—by moving up to about 3.2 light years of the earth and sun, seems to have been a close contender for second place, or perhaps first were its motions more accurately known. Since 3.2 light years is still more than 5,000 times the distance separating Pluto from the sun, it seems reasonable to conclude that the solar system is in no danger of a collision with any neighboring star for at least hundreds of thousands of years yet.

Assuming 6^m as the limit of visibility for the average eye, Kuiper's inventory also reveals that only 53 of the 250 stars listed as the nearest neighbors of the sun and earth are visible to the naked eye. However, if the close binaries could be resolved, five more stars would then be within range of the average eye. Even then, only 23 per cent of the 250 would appear in the panorama of naked-eye objects; and of the whole, only 20, or 8 per cent, are brighter than the sun. Yet, due to the influences of the few relatively bright stars, the average absolute brightness of all is about 71 per cent of the sun's brightness. Moreover, the great majority of the stars in the list are much redder than the sun—135 being, in fact, of spectral class M, and 182 as late as K0. No less than 102 stars in the list, counting the four spectroscopic systems entering as single stars, are members of binary or multiple systems; and 14 others *apparently* belong in this same category. There are six triple systems and one quadruple system—ξ Ursae Majoris, a visual double each of whose components is a spectroscopic binary. Thus it appears that well over 40 per cent of these nearer neighbors are components of binary and multiple systems.

A statistical analysis of these nearer neighbors of the earth and sun can hardly make any claim for completeness without an examination of the number of stars not yet discovered within this sphere of 34.3 light years of the sun; for obviously these could seriously modify all the statistics of the last paragraph. In an attempt to resolve this question, assume that concentric spheres are described, with the sun as the center, in such a manner that the volumes contained between consecutive spheres are all equal to the volume of the first, and the smallest, one. It would appear that, if the stars as now known are uniformly distributed in space, then their numbers should increase in proportion to the number of such spheres involved.

Assume then that, for $n = 1, 2, 3, \ldots$, spheres of volume V_n are chosen in such a way that

$$V_n - V_{n-1} = V_1, \qquad V_0 = 0.$$

Moreover, if p_n be the parallax of the farthest star within the sphere of volume V_n and radius S_n, it follows that

$$V_n = (4/3)\,\pi\,S_n^3 = (4/3)\,\pi\,(3.26/p_n)^3.$$

Since by definition,

$$V_n = n V_1,$$

then also

$$n V_1 = (4/3)\ \pi\ (3.26/p_n)^3,$$

and

$$p_n = 3.26\ (4\pi/3V_1)^{1/3}\ n^{-1/3}.$$

For convenience, now let V_1 be so defined that $n = 27$ when $p_n = 0''.100$. As a result, in cubic light years,

$$V_1 = 46{,}340;$$

and

$$p_n = 0.3\ n^{-1/3}.$$

The analyses are summarized in Figure 1, where the number of stars thus far discovered in the volumes V_n are plotted against n itself. Although the limiting parallax of $0''.095$ corresponds to a value of n slightly greater than 31, in order to account for the other stars listed by Kuiper and not included in the analysis here, it has been assumed that $n = 31$ corresponds to the 250 stars entering into these considerations. Obviously, the verdict rendered by Figure 1 is that the known members of the immediate stellar neighborhood of the sun depart essentially from any assumed uniform distribution in space. The broken line, drawn to illustrate a uniform distribution of 500 stars throughout V_{31}, then suggests that, if the distribution of stars within about 15 light years of the

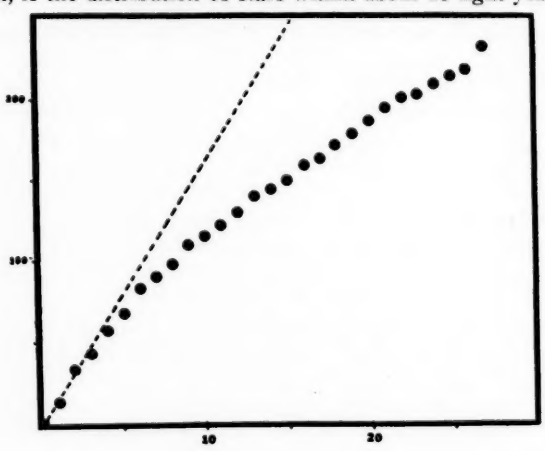

Figure 1. THE SPACE DISTRIBUTION OF THE NEARER STARS. The abscissae are volume-units, the unit being 46,340 cubic light-years; and the ordinates are numbers of stars per unit of volume. The broken line would illustrate uniform space-distribution of 500 stars within 34.3 light-years of the sun.

sun affords any reliable criterion, only about half of the stars within a radius of 34.3 light years of the sun have thus far been discovered.

If the spectra are averaged according to color index, with equal numbers in each of five groups, the means are K9.5, K9.5, K6.5, K8.0, and K9.5, respectively, thereby indicating little evidence of selection as to color and spectrum.

The slope of the curve joining the points in Figure 1 is obviously a measure of the average distance between the stars in the volume indicated. If this "average distance" s is defined by the equation,

$$V = (4/3)\,\pi\,S^3 = N \cdot (4/3)\,\pi\,(s/2)^3,$$

N being the number of stars, it follows that

$$s = 2S/\sqrt[3]{N}.$$

If it is then assumed that $N = 500$ for $S = 34.3$ light years, it is found that, in the vicinity of the sun, the "average" separation is

$$s = 8.6 \text{ light years.}$$

In these explorations into the extent of our knowledge of the stars within 34.3 light years of the sun, two facts, therefore, seem to stand out apart from all the rest. The first perhaps is the incompleteness of our data and the need for more precise information relating to magnitude, spectrum, and parallax for the faint red stars. An outgrowth of such an investigation might well be expected to reveal more close binary systems, more evidence of systematic associations between stars, more evidence on the physical nature of the "average" star, and, in their proper proportions, perhaps more white-dwarfs. The second outstanding fact then is the predominance in space of the intrinsically faint stars—never seen by the naked eye and hardly tempting to the telescopic observer—over those conspicuous giants which easily attract undue attention both of the visual and the telescopic observer. Perhaps the apparent incompleteness of our knowledge of the general run of stars in space is suggestive of a future course of research along such lines.

Melton Memorial Observatory, University of South Carolina.

Some Work on the Structure of the Galaxy

By P. P. PARENAGO*

The study of the galaxy may be developed along the following two lines: (1) by studying the stellar density derived from star counts of all the stars or of stars of a given spectral type; (2) by studying stellar movements (theoretically—the dynamics of the stellar system, practically—the study of the movements of different stars). But before this

*Superintendent of the Department of Stellar Astronomy at Sternberg State Astronomical Institute at Moscow; Professor in the Moscow University.

can be done one must have catalogues of stellar characteristics such as parallaxes, spectral types, radial velocities, variable and double stars and so on. One must also investigate and revise the different relationships, study interstellar light absorption and account for it in all the above-mentioned works.

Ten years ago the author started carrying on work according to this plan. In 1935-1936 a catalogue of stellar parallaxes, absolute magnitudes, and spectral types was compiled. It is being supplemented with new data all the time and now consists of 27,000 stars. The luminosity function was found for stars within a radius of 20 parsecs and also for stars to the sixth apparent magnitude. It corresponded closely to that given by Luyten. Six hundred stars within 20 parsecs were studied. In this small volume of space an asymmetry in stellar motion was found to exist. This shows that the sun's movement towards the standard apex (270°, +30°, 20 km/sec) cannot be called the apex of its movement relative to nearby stars.[1] The pseudo-Cepheids were studied. In a unit of volume 4 pseudo-Cepheids were found for every Cepheid.[1]

The Russell-Hertzsprung Diagram was investigated three times. A diagram for 7,350 stars having the most accurate spectral absolute magnitude was constructed[1]. The following empirical relation for mass, luminosity, temperature or radius was derived

$$M = R^{0.6}\, T^{0.7}$$

or

$$R = L_{bol}{}^{0.7}\, M^{1}$$

all the quantities being expressed in solar units.[2]

The most probable bolometric Hertzsprung-Russell diagram was constructed.[3] On it the lines of equal masses, radii, and density were given. It is also possible to draw lines of equal surface gravity and Einstein's red shift. Another diagram was drawn for 600 stars whose trigonometric parallaxes, visual magnitudes, and spectral types were known with perfect accuracy. The dispersion of stellar magnitudes for stars of the classes A to G is 0.5, for stars of the dwarf K-type 0.4, and for stars of the dwarf M-type 0.3 magnitudes (these being stars of the main sequence).

Other Catalogues of Stellar Characteristics

Besides the above-mentioned catalogue our Institute has the following in its card catalogue: 1) A general catalogue of radial velocities—containing about 10,000 stars. 2) A catalogue of the orbits of 468 spectroscopic binaries and 217 visual double stars. 3) A catalogue of globular and open stellar clusters. 4) A catalogue of galactic nebulae. 5) A catalogue of meridian, astrographic, and micrometric positions and also proper motions of variable stars. 6) A catalogue of complete literature of all variable stars containing about 200,000 refernces in addition to "Geschichte und literature" by Muller, Hartwig, and Prager.

7) A catalogue of variable stars of the Mira Ceti, RR Lyrae, Delta Cephei, and other types. 8) A catalogue of unstudied variable stars in respect to the Plan of investigation of unstudied variables brighter than 12.0 at maximum.[4]

In 1944, we began to compile a catalogue of space velocities of several thousand stars; the components are given in the galactic system of coordinates. This work should give all the kinematical and dynamical characteristics of motions in the Galaxy. Some provisional investigations have now been completed.

The Investigation of Interstellar Light Absorption and Dark Nebulae

Of all the work carried on in Moscow, that of Ambartzumian and Gordeladse[5] is of special importance. It was shown that the bright diffuse nebulae are illuminated by the stars not because of their common origin but because of their accidental encounter. Calculations showed that 1:2000 part of the Galaxy is illuminated enough by the stars (mainly of the B-type) to be registered on the photographs with the 60-inch reflector of the Mount Wilson Observatory with an exposure of one hour. A statistical study by Hubble in these conditions shows only 150 bright galactic nebulae. Therefore there should be 150 x 2000, that is 300,000, diffuse nebulae and these are dark nebulae.

One can assume that the penetrating properties of the 60-inch reflector with an exposure of one hour approximately corresponds to the volume of a cylinder with a radius of 1500 parsecs and a height of 200 parsecs (100 parsecs on both sides of the galactic plane). Therefore in the volume 14×10^8 cubic parsecs there are 300,000 dark nebulae, or one nebula in a cube with the dimensions 17 x 17 x 17 parsecs. This great number of dark nebulae gave Ambartzumian and Gordeladse the idea that these are the main cause of interstellar light absorption. The mean absorption of one dark nebula may be estimated from different methods and is found to be equal to 0.25 magnitude. The mean number of intersections of a ray of vision with dark nebulae is equal to $s\,\phi\,r$ where s is the mean surface section of dark nebulae and equal to about 25 PS^2; ϕ, the number of dark nebulae in a unit volume; r, the path of the ray.

Therefore the mean light absorption per one parsec should be

$$25\ (1/17^3)\ 0^m.25 = 0^m.0013$$

that is about 1 magnitude per kiloparsec. This is equal to the usually adopted amount.

In 1939 Kukarkin[6] when analyzing the color-excesses of stars confirmed the fact that the selective absorption was proportional to λ^{-1}, from which he derived that the mean total photographic absorption near the galactic plane is $2^m.3$ per kps. At the same time he explained[7] Shajn's paradox, that is, that the selective absorption and the surface

brightness of different regions of the Milky Way are not inversely proportional to each other, as should have been expected.

The explanation of Shajn's paradox given by Kukarkin is based on Kreiken's idea that the surface brightness of the Milky Way is affected mainly by near-by dark nebulae. Of course when Kukarkin plotted the surface brightness of the Milky Way and the color-excesses of comparatively near stars (within the distance 160-260 parsecs), he found a marked correlation as was to be expected.

In 1940, the author[9] criticized the commonly adopted custom of characterizing light absorption by a definite number of stellar magnitudes per kiloparsec that is usually 1 magnitude. Lately it has been established that the decrease in space density with the z-coordinate for a great number of homogenous groups of objects is well expressed by the following simple law[10, 11, 12]

$$D(z) = D_0 e^{-z/\beta},$$

where z is the magnitude of z without a sign and β is the degree of galactic concentration. Taking dynamical considerations into account, it is natural to assume that this law may be used for all objects in a large neighborhood around the sun. The distribution is, therefore, characterized by two parameters: (1) the density in the galactic plane D_0, and (2) the degree of galactic concentration β, which is analogous to the height of the homogenous isotermic atmosphere.

These parameters should vary for different subsystems. Assuming that the density of the absorbing matter is also given by the above-mentioned law, the author derived the following formula for the absorption A for any object at the distance r and the galactic latitude b

$$A(r, b) = (a_0\beta/\sin b)\ (1 - e^{-(r \sin b)/\beta}).$$

If $b = 0$

$$A(0, b) = a_0 r$$

Therefore a_0 is the light absorption per unit distance reduced to the galactic plane. It may be seen that the proportionality of the absorption to the distance is true for and only for the galactic plane.

For objects situated behind the main masses of absorbing matter and in the direction of the galactic poles, we have

$$A(\infty, 90^\circ) = a_0\beta.$$

If we assume that the absorption is due only to elementary dark nebulae, the value of a_0 has the following meaning

$$a_0 = (3\pi/8)\ \overline{R}^2\ \epsilon\ \phi_0$$

where $\overline{R}$ is the mean radius of dark nebulae which are assumed to be spherical; ϵ, the mean absorption in a mean dark nebula; and ϕ_0, their space density, when $z = 0$.

The author used the photoelectrical and other determinations of color-excesses and also Hubble's and Shapley's counts of extragalactic nebu-

lae, which makes altogether about 3,000 determinations of absorption, and obtained the following mean data[13]:

$$a_0 = 3^m5/\text{kps},\ \beta = 100 \pm 4\ \text{ps},\ \epsilon = 0^m25$$
$$\phi_0 = 5 \cdot 10^{-4}\ \text{dark nebulae per cubic parsec}$$
$$\overline{R} = 2.7\ \text{parsec.}$$

By analyzing observational material it was possible to pick out those regions of the sky for which a_0 and β could be assumed to be constant within the limits of observational errors. The sky was divided into 100 regions in which a_0 varied from 0.7 to 9.0 magn. per kps. β was found to be practically constant.

The author developed a convenient tabular and graphical method for correcting the photometrical distance for the influence of light absorption. β being known, the mean mass of a dark nebula could be determined and was found to be equal to 3.5 solar masses. Taking ϕ_0 and $\overline{R}$ into account he derived the total mass of dark nebulae in the Galaxy which equaled 10^8 solar masses. This wholly agrees with that found by Fessenkoff in 1940 with the help of a quite different method.[14]

The mean density of matter in dark nebulae equals 10^{-24} grams per cubic centimeter. The total number of dark nebulae in the Galaxy is estimated to be about 45,000,000.

Stellar Movements

The galactic rotation is commonly studied by using Oort's formulae which are insufficient when a great distance from the sun is considered as they neglect the second and higher powers of r/R. In 1938 Camm[15] (and in 1940 independently the author) suggested the following function for analyzing galactic rotation:

$$f(R, R_0) = (V_r - V_0 \cos\lambda)\ \text{cosec}\ (l - l_0)\ \sec b = R_0\,[\omega(R) - \omega(R_0)].$$

This function should be called Camm's function. From the first equation it is evident that this function can be calculated from observed radial velocities (corrected for the sun's motion toward the apex) if the galactic longitude l_0 of the galactic center is known. The second equation shows that the angular velocities at different distances from the galactic center can be calculated from Camm's function, if $\omega(R_0)$ is known. In contrast to Oort's formula Camm's function is free of the limitation above mentioned. Developing $\omega(R)$ into a series around $R = R_0$ and neglecting the second and higher powers of r/R we obtain the commonly used Oort's formula.

By analyzing the radial velocities of Cepheids, O and B stars, planetary nebulae, and open clusters with the help of Camm's function, and taking the light absorption into account the author comes to the following conclusions:[16]

(1) The use of Camm's function is a very convenient method for

the studies of the galactic rotation at great distances from the sun.

(2) The angular and linear velocities at different distances from the galactic center were derived. The angular velocities diminish monotonously from the center to the boundaries of the Galaxy in good numerical agreement with the theory of a stationary Galaxy and the most probable Chandrasekhar's models of a nonstationary Galaxy.

(3) Oort's "constants" A and B are not constants but variables. Their values depend upon the distance R from the galactic center and upon the subsystem considered. For the subsystems mentioned above, A_0 (that is for sun's distance) is found to be equal to 0.0197 (0.0004 mean error).

(4) By comparing the above-mentioned results with the observed rotation of the Andromeda Nebula, and by assuming its similarity to our Galaxy, the conclusion may be drawn that the place in the Andromeda Nebula analogous to the one occupied by the sun is located far behind its commonly photographed parts and on the border of regions detected by photoelectrical observations.

REFERENCES

[1] Parenago, *Publ. Sternberg State Astr. Instit.*, Moscow, vol. xiii, part 1, 1940.
[2] Parenago, *Astr. Journal Sov. Union*, **16**, Nr. 6, 1939.
[3] Parenago, *Astr. Journal Sov. Union*, **21**, Nr. 5, 1944.
[4] Kukarkin, *Pop. Astr.*, **45**, 86, 1937.
[5] Ambartzumian and Gordeladse, *Abastumani Bull.*, Nr. 2, 1938.
[6] Kukarkin, *Astr. Journal Sov. Union*, **17**, Nr. 1, 1940.
[7] Kukarkin, *Idem.*
[8] Kreiken, *ZS. f. Ap.*, **17**, 170, 1939.
[9] Parenago, *Astr. Journal Sov. Union*, **17**, Nr. 4, 1940.
[10] Oort, *Bull. Astr. Instit. Netherl.*, **6**, 252, 1932, see also prec. refer, p. 7 and fig. 1.
[11] Greenstein, *Astroph. Journ.*, **87**, 578, 1938.
[12] Kukarkin, Uupubl. results for different types of variable stars.
[13] Parenago, *Astr. Journ. Sov. Union*, **22**, Nr. 3, 1945 (in press).
[14] Fessenkoff, Doklady Akademii Nauk (*Comptes Rendus Acad. Sc. USSR*), **28**, Nr. 7, 593, 1940.
[15] Camm, *Monthly Notices RAS*, **99**, 71, 1938.
[16] Parenago. This paper was finished in 1940 and was read several times at the different meetings. The paper was in press but in autumn 1941 the type was destroyed. Yet the paper anew goes in press.

MOSCOW, JUNE, 1945.

Marvelous Voyages—IX

J. B. S. Haldane "The Last Judgment"

By LAURENCE J. LAFLEUR

J. B. S. Haldane is the author of the essay-story "The Last Judgment," which appeared in book form both under its own title and in another work called "Possible Worlds." In this the author discusses the most probable end of the world, an end produced by tidal evolution causing the moon to approach the earth and break up into fragments. This end would come in not less than fifty billion years, but Haldane considers this period too long to consider human beings as remaining recognizably human: "Four hundred million years ago our ancestors were fish of a very primitive type. I cannot imagine a corresponding change in our descendants." So he assumes that tidal evolution is hastened by man's use of tides as a source of energy, bringing the end to a period only forty million years in the future.

The earth and the other planets were formed 1,834,000,000 years ago when a tidal wave was caused by the near approach to the sun of another star. The earth's original period of revolution "was then only very slightly shorter than now; but there were 1800 days in it, each lasting only a fifth of the time taken by a day when men appeared on earth. The liquid earth spun round for a few years as a spheroid greatly expanded at the equator and flattened at the poles by its excessive rotation. Then the tidal waves raised in it by the sun became larger and larger. Finally the crest of one of these waves flew off as the moon. At first the moon was very close to the earth, and the month was only a little longer than the day.

"As the moon raised large tides in the still liquid earth the latter was slowed down by their braking action," and the moon "rose gradually farther and farther from the earth, which had now a solid crust, and the month, like the day, became longer. When life began on the earth the moon was already distant, and during the sixteen hundred million years before man appeared it had only moved to a moderate degree farther. . . At this time the effect of tidal friction was to make each century, measured in days, just under a second shorter than the last." But human beings hastened tidal evolution by using tidal power, and after the race was in existence for a million years, the tidal power utilized aggregated a trillion horsepower, which caused the day to lengthen appreciably. "By the year five million the human race had reached equilibrium; it was perfectly adjusted to its environment, the life of the individual was about three thousand years. . . The tidal energy available was now fifty trillion horsepower. Large parts of the planet were artificially heated. The continents were remodelled. . . Human evolution had ceased. . . The almost complete abolition of the pain sense which was

carried out before the year five million was the most striking piece of artificial evolution accomplished."

By the year eight million the length of the day had doubled, the moon's distance had increased by twenty per cent, and the month was a third longer than it had been when first measured. It was realized that the earth's rotation would now diminish rapidly, and a few men began to look ahead, and to suggest the colonization of other planets. The older expeditions had all been failures. The projectiles sent out from the earth had mostly been destroyed by air friction, or by meteorites in interstellar space, and those which had reached the moon intact had generally been smashed by their impact on landing." The projectiles used for these attempts were metal cylinders sent from vertical guns several kilometers in length. The air was evacuated from the guns to lessen resistance, and a series of mild explosions gave the projectiles an initial velocity of five kilometers per second. Further impetus was given on the rocket principle. Many different devices were used to check the motion on arrival, but later voyages were made on the sailing principle, using the sun's radiation pressure on a metal foil of a square kilometer or more of surface, extruded from the projectile after leaving the atmosphere.

Colonization of Mars and Venus was difficult: on Mars because of a hostile form of life, on Venus because of a scarcity of oxygen and the existence of a form of life based on amino acids the mirror image of those used on earth, and which proved poisonous to men. Mars was never conquered; Venus only by synthesizing bacteria to attack and exterminate the native life of Venus and by evolving under artificial conditions on earth and over a period of ten thousand years a race of men capable of living at one tenth of the oxygen pressure prevalent on earth.

"During the last few million years the moon approached the earth rather rapidly. . . In the year 36,000,000 the moon was at only a fifth of its distance from the earth when history had begun. It appeared twenty-five times as large as the sun, and raised the sea-level by some 200 meters about four times a year. The effects of the tidal strain raised in it by the earth began to tell. Giant landships were observed in the lunar mountains, and cracks occasionally opened in its surface. Earthquakes also became rather frequent on the earth. Finally the moon began to disintegrate. It was so near to the earth as to cover about a twentieth of the visible heavens when the first fragments of rock actually left its surface. The portion nearest to the earth, already extensively cracked, began to fly away in the form of meteorites up to a kilometer in diameter, which revolved round the earth in independent orbits. For about a thousand years this process continued gradually. . . The end came quite suddenly. . . The depression in the moon's surface facing the earth suddenly opened and emitted a torrent of white-

hot lava. As the moon passed round the earth it raised the temperature in the tropics to such an extent that rivers and lakes were dried up and vegetation destroyed. . . Dense clouds were formed and gave some protection to the earth. But above them the sea of flame on the moon increased in magnitude, and erupted in immense filaments under the earth's gravitation. Within three days the satellite had broken up into a ring of white-hot lava and dust. . . Within a day from the moon's break-up the first large fragments of it had fallen on the earth. The particles formed from it were continually jostling, and many more were subsequently driven down." The earth's tropical regions were "buried many kilometers deep under lunar fragments, and the remainder, though some traces of the former continents remain, had been submerged in the boiling ocean." All life was killed, and the earth ended by possessing "a belt of enormous mountains in its tropical regions, separated from the poles by two rings of sea."

Men on Venus intend subsequently to recolonize the earth, and to erect huge "artificial mountains on both planets which will extend above the Heaviside layer and enable continuous radio-communication instead of light signals to be used between the two." Then it is proposed to colonize Jupiter by breeding a race of dwarfs with thick bones, and providing their projectiles with great stocks of fuel. If colonization of Jupiter succeeds, the outer planets will be attempted; then, in another 250,000,000 years, the planets of other stars. The whole galaxy is to be populated in less than eighty trillion years, and then other galaxies will be attempted.

Errors

1. The age of the solar system is given as less than two billion years, which is on the short side.

2. In the formation of the moon from the earth, why should the tides raised by the sun be so great? The tidal force of the sun would be no greater then than now, and should raise tides in a liquid earth approximately as it now does in the sea.

3. Why should the solar tides become greater and greater? There is nothing in their nature to produce pulsation or to give any cumulative effect.

4. Assuming the earth's size at its inception to be about what it is now, it would have to be rotating almost three times as fast as stated before its gravitational pull would be equalized by the centrifugal force of rotation and thus make possible the throwing off of the moon.

5. As shown by Jeans, ejected matter would be sent out in one or two filaments rather than as a single globule.

6. The moon, if ejected and revolving in a period of little more than a day, would be within Roche's limit and should be torn apart immediately.

7. Each century is about half a minute shorter than the previous

one, not just a second.

8. The general course of tidal evolution, according to the best current theory, is that given by Haldane, but two questions will inevitably occur to the reader: could human use of tidal power have such a great influence on astronomical events, and, second, is the stated tidal power actually available? An estimated answer to the first problem is not difficult to obtain: in twenty-five million years the moon is to return to its present distance, and in that time most of the energy of the earth's rotation will be expended principally in producing the horsepower in question. Simple calculation shows that Haldane's figures are of the correct order of magnitude, and that the increase in the rate of tidal evolution is approximately what he states. But Haldane is incorrect in presuming that this horsepower would be available. The maximum can be calculated by assuming that full advantage is taken twice a day of each fall of tide over the whole surface of the oceans. The exact value of the result depends upon the extent of the ocean of the future and the average height of the tides, but it certainly is of the order of 100 billion horsepower, not the 50 trillion suggested by Haldane.

9. The theoretical maximum would hardly be attained. It would require the piping of the upper parts of all the oceans; or, more plausibly, dividing the oceans into cells, each cell connected with another 90 degrees of longitude removed, so that a tidal height of water would be allowed to flow through the connecting pipes four times each day. Any more economic scheme would deliver less horsepower.

10. As tidal evolution proceeds, the amount of power available will be sharply curtailed. The intensity of the solar component will not vary appreciably, but it will occur only one forty-eighth as frequently when the day is forty-eight times as long. The intensity of the lunar component varies inversely as the fourth power of the lunar period, and therefore the available energy per tide will drop to about one-tenth of its present value. At the same time the number of tides varies inversely as the time it takes the moon to travel from meridian to meridian as viewed from some point on earth, and drops to zero when the day equals the month in length. When both day and month are forty-eight of our present days, the tidal power available would not be much in excess of one per cent of that available at present, or one five-hundredth of one per cent of what Haldane expects to be used.

11. The earth's rotation would not diminish more rapidly after the day had doubled: on the contrary, the effect diminishes with the diminishing amount of available tidal energy. When the moon starts its return journey, in fact, the lunar tides will accelerate rather than retard the earth.

12. It is inconceivable to this writer that we will have to wait a period millions of years to send expeditions to the moon, Mars, and Venus. Fewer centuries will probably be needed than Haldane allots

millions of years. The problems involved are serious, but not greater than those involved in building a modern competitive battleship.

13. To send an object out of a tube "several" kilometers in length—say four—with a muzzle velocity of five kilometers per second would mean a force of over three thousand g's. Men can stand only about ten, as far as we know at present. If the force is applied as a "series of explosions," the force must be still greater. These explosions are hardly "mild."

14. The sailing principle is not suitable for rockets. Because there is no atmospheric resistance in interplanetary space, foil wings may be made as thin as you please without breaking: but if radiation pressure is enough to supply any considerable propulsion it would break a thin foil. Since stiffening must be supplied, the foils would be uneconomically heavy. Besides, a sailing vessel can use the wind to go in almost any direction because water resistance on the keel can be used to alter direction, but no such resistance is available in space and radiation pressure will send a ship directly away from the sun and in no other direction.

15. Human beings have always shown a genius for waging war, and I doubt if any inhabitants of Mars could withstand us, unless they had as great a material culture as we together with a strong competitive spirit. But in that case the Martians would probably have sent rockets here first.

16. Even today men meet unusual conditions by using instruments, not by adapting their bodies over a period of thousands of years. Flying in the stratosphere has brought forth oxygen masks, pressure suits, and pressure cabins; and I see no reason to suppose that our descendants in the remote future will have less knowledge, intelligence, and initiative than ourselves.

17. If the surface of the earth and moon are seven thousand miles apart when disintegration begins (which is two thirds of Roche's limit), the moon will still subtend an angle of only fifteen degrees at the nearest point on earth. This is quite far from covering a twentieth of the visible heavens, but one one-hundred and twenty-ninth of one hemisphere.

18. From the description, it appears that Haldane expects the moon to continue to present the same face to the earth. As we do not understand why it does so now, we cannot judge whether it is likely to do so in the remote fture; but if so the earth's tidal pull is not likely to produce extensive cracking of the moon's surface until it is actually torn apart. In any case the distintegration of the surface is apt to be a continuous process with that of the rest of the moon.

19. It is difficult to see why lava should erupt from the moon. The pressure to cause the eruption would be lacking, as the earth's influence in tearing the moon apart will lessen, not increase pressures, especially in a non-rotating body.

20. The source of the heat is also doubtful: there seems little reason to believe that the interior of the moon is excessively hot, to begin with, and the process of breaking up would involve little friction to heat it and considerable expansion to cool it.

21. Fragments of the moon will not fall to the earth in one day or anything like it. These fragments will be travelling around the earth in essentially parallel paths and adjacent ones with essentially the same velocity. Even though the fragments would form a very dense ring, and though jostling would be continual, fragments would fall only at rare intervals. The destructive effect would be great, but probably not greater than that of bombing in modern warfare. In time the earth's tropical regions would be covered with fragments, and a new geography produced, but man would have time to adapt to each change step by step.

22. It is unlikely that enormous mountains would be produced by the fall of lunar fragments. Large fragments would hit with enough energy to liquify or vaporize the region of contact, and small particles would be carried away from the tropics by violent winds which would develop from the novel conditions.

23. That regular interplanetary communication between men living on two planets should be restricted to the use of light for millions of years is neither plausible nor creditable to the ingenuity of our descendants. Besides the use of ultra short-wave radio and cosmic rays, it seems almost a certainty that another possible method of communication will be discovered every few years for some time to come. In forty million years it is likely that a plethora of methods will be known.

24. It would probably be much simpler to colonize Jupiter's Galilean satellites rather than Jupiter itself. No known factors would make them less suitable, and several more suitable, than their primary.

Abastuman Mountain Observatory

By VICTOR KRASILNIKOV

The first Soviet mountain astro-physical observatory began to function eight years ago. It was built at a height of 1,243 metres above sea level on Mount Kanobili near Abastuman. Initiated by the Mathematical and Natural Science section of the Georgian branch of the Academy of Sciences of the U.S.S.R. in 1941, it passed under the aegis of the newly formed Georgian Academy of Sciences. Its director is E. Kharadze, Georgian astronomer. The observatory is equipped with up-to-date instruments adapted for the study of intricate problems of astrophysics and stellar astronomy.

The observatory has already won a leading place among astronomical institutions of the Soviet Union. Its staff has compiled a catalogue

of color indices of 9,000 stars and anagalactic nebulae, 2,500 of which were entered during the war. Photoelectric determination of their color equivalents according to the type of stars in the Milky Way has been completed. In 1942 Tevzadze, a member of the observatory's staff, discovered two new comets which are at present being studied. The observatory maintains continuous observation of the sun supplying information to research institutes engaged in studying the connection between solar processes and terrestial phenomena.

The observatory has devised a new method of electro-photometric observation with the help of which V. Nikonov has achieved a degree of accuracy in electro-photometric measurement not inferior to that of American observatories.

The staff of the Abastuman Observatory did not relax its observations and scientific work during the war, evidence of which is given in the two latest issues of the observatory's bulletin, which sum up its work for 1942-1944.

The Planets in December, 1945

NOTE: Greenwich Civil Time is employed unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours, Central Time, 6 hours, etc. The phenomena are described as they are to be seen from latitude 45° N. The data are taken chiefly from the *American Ephemeris and Nautical Almanac.*

Sun. The sun will reach its greatest declination south during this month. Speaking precisely, this will occur on December 22 at 5:04 A.M., Greenwich Civil Time, and will mark the time of the winter solstice. The sun will change its declination from —20° 43′ to —23° 27′ and back to —23° 9′ in the course of the month. Its eastward motion will take it from Ophiuchus into Sagittarius.

Moon. The phases of the moon will occur as follows:

	d	h
New Moon	Dec. 4	18
First Quarter	12	11
Full Moon	19	2
Last Quarter	26	8

Mercury. At the beginning of the month Mercury will be moving westward toward the sun. It will continue this retrograde motion during the first half of the month after which it will move eastward at an accelerated rate. It will be at inferior conjunction, that is between the earth and the sun on December 7, and hence invisible for some days before and after this date. By December 26 it will have moved to a position of greatest elongation west, and on and near that date it will rise about an hour and a half before the sun, and, under favorable conditions of sky and horizon, should be visible.

Venus. Venus will continue to remain west of the sun during December. Its motion eastward will be more rapid than that of the sun and by the end of the month will be only about 8 degrees west. It will therefore be quite inconspicuous in the morning twilight.

Mars. On December 5, Mars will stop a slow motion eastward and begin a retrograde motion which will continue through the rest of the month. It will cross the meridian soon after midnight. Because of its high northern latitude, it will be very favorably situated for observations in the northern hemisphere.

Jupiter. Jupiter will be lagging behind the sun in their motion eastward. It will consequently rise earlier from morning to morning and will be the brilliant morning star during this period. It will be a few degrees north of the first magnitude star Spica.

Saturn. Saturn will be in the same general region of the sky as Mars. Therefore, it and Mars will constitute an interesting pair of celestial objects for study by the amateur and for observation by the person who may have a telescope at his disposal for his pleasure and for the entertainment of his friends.

Uranus. Uranus will be in opposition to the sun on December 7. It will, therefore, rise at sunset and set at sunrise. It is not of very great interest, as, if seen at all with the unaided eye, it cannot be distinguished from a faint star. In a telescope it discloses a small disc but very little characteristic marking.

Neptune. Neptune will be coming into more favorable position. On December 30 it will be in quadrature, 90° west of the sun. It will then rise at midnight and be observable during the latter half of the night. It will be a few degrees south of the equator in Virgo.

Occultation Predictions for December, 1945

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b;* apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

				IMMERSION				EMERSION			
Date 1945	Star	Mag.	Greenwich C.T.	*a*	*b*	Angle E from N		Greenwich C.T.	*a*	*b*	Angle E from N
			h m	m	m	°		h m	m	m	°
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′											
Dec. 12	290 B.Aqar	6.4	2 39.9	−0.1	+0.8	28		3 30.9	−0.5	−1.7	277
12	30 Pisc	4.7	23 57.4	−0.7	+1.9	17		0 57.2	−2.1	−1.0	275
13	33 Pisc	4.7	1 50.3	−1.2	−0.2	66		2 58.5	−0.7	0.0	231
15	85 Ceti	6.3	23 11.5	−1.3	+1.2	86		0 13.2	−0.8	+2.2	212
16	30 B.Taur	6.5	21 46.8	−0.3	+1.3	86		22 41.0	−0.3	+2.0	225
17	148 B.Taur	6.0	6 20.8	−1.1	+1.2	32		7 9.0	−0.6	−2.4	297
17	162 B.Taur	6.3	9 29.3	+0.6	−2.6	131		10 1.5	−0.3	+0.7	208
21	9 Canc	6.2	5 22.7	−1.7	+1.4	73		6 35.2	−1.8	−1.3	303
23	107 B.Leon	6.3	9 9.4	..	..	180		9 46.7	−3.5	+2.1	234
25	ν Virg	4.2	10 5.5	−0.8	−2.7	163		11 11.3	−2.4	−0.3	266
29	22 B.Libr	6.4	12 17.2	−1.6	−0.7	127		13 44.7	−1.9	−1.0	297
30	ζ Libr	5.6	11 52.2	+1.2	−3.8	186		12 24.8	−4.1	+3.4	233

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′

Dec. 12	290 B.Aqar	6.4	2	34.4	+0.1	+2.3	6	3	16.5	−1.8	−2.5	292
13	33 Pisc	4.7	1	25.1	−1.3	+1.1	44	2	39.5	−4.5	−0.1	248
13	24 B.Ceti	6.0	4	33.1	−1.4	−2.8	114	5	11.3	+0.1	+2.2	188
15	85 Ceti	6.3	22	51.3	−0.5	+1.6	68	23	53.4	−0.7	+1.8	234
16	30 B.Taur	6.5	21	42.1	+0.2	+1.3	75	22	33.9	0.0	+1.6	239
17	148 B.Taur	6.0	5	53.7	−1.4	+1.5	39	6	55.7	−1.4	−1.6	283
21	9 Canc	6.2	4	53.6	−1.0	+1.7	72	6	3.1	−1.7	−0.2	294
24	BD+12°2284	6.4	10	10.3	..	..	49	10	37.0	..	..	12
29	22 B.Libr	6.4	12	2.2	−0.2	−1.8	166	13	3.5	−2.7	+1.1	261
31	ψ Ophi	4.6	12	23.8	−1.0	+0.9	102	13	38.6	−1.1	−0.2	309

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

Dec. 13	33 Pisc	4.7	0	51.1	0.0	+3.7	357	1	32.0	−3.5	−0.8	295
13	24 B.Ceti	6.0	3	44.7	−2.1	0.0	77	4	55.8	−0.9	+1.2	213
16	147 B.Arie	5.8	11	41.0	+0.8	−4.2	141	12	1.7	−0.7	+2.9	188
17	148 B.Taur	6.0	5	10.1	−0.5	+3.5	14	6	0.1	−2.8	−1.4	293
20	58 Gemi	6.0	14	56.4	..	..	172	15	13.1	−1.7	+2.2	209
21	9 Canc	6.2	4	35.0	+0.2	+2.1	53	5	23.6	−1.0	−0.1	305
24	BD+12°2284	6.4	9	1.7	−1.1	+0.9	99	10	16.9	−1.5	−0.8	309

OCCULTATIONS VISIBLE IN LONGITUDE +98° 0′, LATITUDE +30° 0′*

Dec. 10	128 B.Capr	6.5	2	29.0	+0.1	+1.4	24	3	19.2	−1.0	−1.7	285
12	290 B.Aqar	6.4	2	13.5	−0.8	+1.6	28	3	20.1	−1.6	−0.7	265
12	30 Pisc	4.7	23	10.9	+0.1	+4.2	354	23	50.9	−4.0	−1.2	296
13	33 Pisc	4.7	1	2.3	−1.9	+1.3	55	2	24.4	−1.6	+1.0	231
14	26 Ceti	6.2	6	3.0	−0.1	+3.4	2	6	35.1	−1.0	−3.3	302
15	85 Ceti	6.3	22	34.0	−0.4	+1.2	80	23	30.3	−0.4	+2.0	223
17	148 B.Taur	6.0	5	31.2	−2.1	+0.6	69	6	51.0	−1.8	+0.3	248
21	9 Canc	6.2	4	34.6	−1.0	+0.6	99	5	46.2	−1.5	+1.1	262
24	BD+12°2284	6.4	9	36.8	−2.2	−0.2	107	11	4.1	−1.8	−2.0	316
31	ψ Ophi	4.6	12	18.2	−0.2	−0.8	142	13	25.7	−1.8	+0.9	271

*Computed by Edgar W. Woolard and Paul Herget; communicated by Commodore J. F. Hellweg, Superintendent U.S. Naval Observatory.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

Thanks to excellent publicity attained by cordial cooperation of the press and also to scores of official postal cards to former observers the Perseid meteors of August, 1945, were widely observed not only by A.M.S. members but by many others who efficiently helped. The amount of data is so large that these Notes will be confined to preliminary remarks and a condensed table. In the next Notes it is planned to discuss more fully what was deduced from the tabular matter, and give in more detail the results of certain individuals or groups, denoted by an * in the following table, which should be taken up at greater length.

In general, on August 9 to 13 the weather was unfavorable over many states from which normally we should receive numerous reports. Those who did manage to observe in these regions did so under poor conditions. The number of fireballs, Perseid or sporadic, was small, and few trains of a duration greater than 5 seconds were noted. It will be seen, however, that for those observers, situated at some height above sea level and favored with excellent skies, the rate on August 11 and 12 in many instances was greater than one per minute. On the contrary, for some observers in cities on those same nights, who had poor skies, the rate was almost zero! This emphasizes the necessity, when observing meteors, of

having really clear skies. The writer for instance, working on the lawn at Flower Observatory in Upper Darby just 5 miles west of the center of Philadelphia, where we have city lights all around us, and for the critical nights having much haze in addition, had very low rates compared to those with fine conditions. The same is true for many others. To see meteors in their real numbers one *has* to be away from artificial light,—*i.e.*, far from any city or large town—and have clear, moonless skies. Persons with poor eyesight of course have a serious additional handicap.

In the table, the data in columns 4 and 5 are copied as given. Many did not give the factor F or any notes by which it could be derived. When the rates are fairly high, the factor may be assumed as 1.0. In column 6 when no time is given we are justified in assuming that War Time for the region of the observer was used. The rates usually are not worked out if F = 0.4 or less, or if the observation period covered less than 30 minutes. The rates given are *uncorrected;* to get corrected rates divide the uncorrected by F. Those observers who plot must per force get smaller rates than those who only count, other factors being equal. New observers particularly may take up to 5 minutes to plot and record a meteor; no one can do it properly in less than 30 to 40 seconds. Due to the great difference in the experience of those who plotted, it has not seemed wise to attempt to put in the correction for rate due to this type of loss. No amount of exhortation keeps many people from counting by pairs or groups. While their results are most gladly received and are interesting, they are not directly comparable with indivdiual counts. Further we are rarely certain whether, in such counts, duplicates are omitted. If they are, dividing the reported number by the number of observers must always give individual rates much too small. Hence for all cases, not single observers, I have not attempted to derive the rates. What they could give us would be of qualitative rather than quantitative value. For groups it is usually not practicable to give each individual's name; the leader's name alone appears. In column 11 is found the total number of observers, if known. However, to everyone, whether their names appear or not, our sincerest thanks are due. Without their aid and good will these observing programs could not be undertaken and meteoric astronomy would suffer seriously.

In the table the columns, by number, give: 1 station and observer, 2 direction observer watched, 3 date in old astronomical time beginning at noon of civil date, 4 time observations began and 5 when they ended, 6 kind of time used, 7 total number of minutes observed (no allowance made for time lost in plotting or recording), 8 number of meteors observed, 9 factor for period, 10 number of meteors per hour, 11 number of observers, 12 type of observation: c count only, d each meteor described but not plotted, p meteors plotted.

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
Canada, Br. Columbia											
W. Vancouver		1945									
Edmonds, A.	NW	8 11	12:45	13:30		45	25	0.6	33	1	4
Vancouver											
Smith, K. D.		8 12	10:	11:		60	29	0.6	29	1	c
Okinawa, U.S.S. Pine Island											
*Wood, Lieut. R. J.	Z	8 11	11:28	19:10	GCT	452	645	1.0	87	1	cp
" "	Z	8 12	13:20	18:00	"	255	462	0.8	109	1	cp
Alabama											
Florence											
Binkley, A. M.		8 11	15:	15:45		45	23	0.7	31	1	c
"		12	12:	12:20		20	8	0.7	..	1	c

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
Arizona											
Tucson											
Bulinson, M. A.	NxE	8 11	12:00	13:00	MST	60	66	...	..	2	CP
Tempe											
Bridges, Mrs. D.	NE	8 12	9:30	11:00		60	13	...	13	1	C
Prescott											
Jamison, Miss E.		8 12	12:00	12:30		30	31	1.0	..	2	C
Casa Grande											
Rust, M. D.		8 12	13:00	14:00		60	40	1.0	..	2	C
Arkansas											
Marianna											
Mixon, R. H.		8 11	11:00	15:45		225	24	0.4	..	1	C
"		12	9:00	15:30		375	28	0.4	..	1	C
California											
Davis											
Beetle, Mrs. D. E.		8 11	14:18	16:02		104	48	1.0	28	1	P
" "		12	12:35	14:28		113	39	0.8	21	1	P
Fresno											
Blaser, J.		10	10:	11:		60	7	1.0	7	1	C
"		10	10:	11:		60	7	1.0	7	1	C
"			14:15	15:15		60	47	1.0	47	1	C
"		11	10:	11:		60	21	1.0	21	1	C
"			14:40	15:45		65	81	1.0	75	1	C
"		12	10:	11:		60	16	1.0	16	1	C
Bostick, Dr. L. B.		8 11	9:05	10:05	PWT	60	5	...	5	1	C
" "			11:20	11:40	"	20	12	...	36	1	C
" "			15:25	15:55	"	30	16	...	32	1	C
" "		12	16:00	16:32	"	32	43	...	81	1	C
" "		Misc.	.....	.....		..	11	...	..	1	C
Palo Alto											
Cuthbertson, A. M.		8 10	9:35	10:35		60	8	...	8	1	C
" "			13:00	15:30		150	38	...	15	1	C
La Canada											
*Heuchman, J. M.		8 12	10:30	15:30	PWT	300	470	0.9	94	1	C
Yuba City											
Hurdle, Mrs. H. F.		8 9	10:30	12:30		120	24	...	12	1	C
" "		10	10:15	11:15		60	32	...	32	1	C
" "		11	10:	10:30		30	29	...	58	1	C
" "		12	9:25	10:35		70	34	...	..	1	C
" "		9 4	12:00	12:30		30	11	...	22	1	C
Big Basise (8 in group)											
*Kirby, Miss E.	4Q	8 9	13:17	14:57		100	232	...	..	4	D
" "	4Q	10	13:17	14:57		100	305	...	..	4	D
Pasadena											
Stowe, B.		7 28	10:45	12:02	PST	80	5	0.4	..	1	P
"		8 3	11:10	12:45	"	95	12	0.9	..	1	P
"		4	11:15	12:50	"	95	14	0.8	..	1	P
"		10	10:55	12:10	"	..	10	0.6	..	1	P
"		11	10:55	15:45	"	..	143	0.9	29	1	PC
Connecticut											
Hartford											
Ehman, Mrs. C.		8 11	8:10	12:00	EST	230	49	0.8	13	1	C
" "		13	8:30	10:30	"	120	7	0.7	4	1	C
Ehman, C.		11	8:10	12:00	"	230	86	0.8	..	1	P
"		13	8:30	10:30	"	120	8	0.7	..	1	P
"		13	13:45	14:30	"	45	4	0.4	..	1	P
N. Colebrook											
McClave, Miss E. L.		8 11	9:	10:30		90	55	.8	36	1	C
Lakeville											
Rosebrugh, D. W.		8 11	9:05	9:20		15	11	.8	44	1	C

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
Manchester											
*Spiess, E. and											
Troop 91 B.S.A.		8 10	9:00	12:00		180	65	1.0	..	g	C
" "			12:00	14:00		120	72	1.0	..	g	C
" "		11	9:00	12:00		180	213	1.0	..	g	C
" "			12:00	13:00		60	115	1.0	..	g	C
" "			13:00	14:00		60	68	0.6	..	g	C
Naugatauk											
Wrinn, J. J.	N	8 4	13:03	14:09		66	15	0.8	..	1	P
"		9	13:33	14:36		58	6	0.5	..	1	P
"		11	12:50	13:25		35	18	0.8	..	2	P
"	N		13:39	14:05		26	21	0.7	..	2	C
Merkt, Mr. and Mrs.	W		12:49	14:05		64	34	0.7	..	2	C
Wrinn, Miss A.	NE		12:50	14:05		65	37	0.7	..	2	C
Elliott, Dr. and Mrs.	N		12:49	14:05		62	38	0.7	..	2	C
Beerbaum, H.	NW		12:40	14:04		60	22	0.7	..	2	C
Delaware											
Wilmington											
Hukill, R. M.		8 10	14:00	16:00		120	18	.7	9	1	P
Florida											
Sarasota											
Griffith, Miss J. T.		8 11	12:35	14:35	EWT	120	28	.7	14	1	P
Boca Raton											
Rasmussen, H.	E	8 11	10:45	11:55		70	16	.7	14	1	C
"	E		12:20	13:50		90	23	.7	16	1	C
"	E		15:05	16:00		55	12	.7	13	1	C
Idaho											
Buhl											
Sandmeyer, Miss E.		7 28	12:05	13:05		60	4	...	4	1	C
" "		29	13:10	14:10		60	6	...	6	1	C
" "		31	12:00	13:00		60	8	...	8	1	C
" "		8 3	15:50	16:50		60	9	...	9	1	C
" "		4	13:15	16:15		60	11	...	11	1	C
" "		8	16:00	17:00		60	19	...	19	1	C
" "		9	11:00	11:45		45	9	...	12	1	C
" "			11:00	11:45		45	5	...	7	1	C
O'Neill, Mrs. D.			11:00	11:45		45	8	...	10	1	C
Sandmeyer, Miss H.		12	11:05	13:57		112	15	0.5	8	1	P
Sandmeyer, Miss E.		16	11:00	14:15		195	10	1.0	3	1	P
Illinois											
Joliet											
Preucil, F.		8 6	10:50	11:20	CWT	30	7	...	14	1	C
"		9	10:15	11:15	"	60	4	0.6	4	1	C
"		11	16:35	16:55	"	20	7	0.6	21	1	C
"		12	9:45	11:45	"	120	32	0.9	16	1	C
"			12:00	13:00	"	60	21	0.9	21	1	C
"			15:00	16:00	"	60	28	0.9	28	1	C
"		13	10:00	10:30	"	30	3	0.4	6	1	C
Preucil, W.		9	10:15	11:15	"	60	7	0.6	7	1	C
Huey, Dr. W.		12	9:45	10:45	"	60	6	0.9	6	1	C
Price, R. L.			10:45	11:45	"	60	24	0.9	24	1	C
Price, R.			10:45	11:45	"	60	28	0.9	28	1	C
Preucil, W.		13	10:00	10:30	"	30	4	0.4	8	1	C
Indiana											
Elkhart											
Swihart, T.		8 8	13:40	15:40		120	18	1.0	9	1	P
"		9	11:20	12:15		55	6	0.5	6	1	P
"		12	9:23	13:23		240	42	1.0	10	1	P
Iowa											
Sibley											
Fitzsimmons, C. S.		7 30	11:15	12:45	CWT	90	8	0.9	6	1	P
" "		8 2	12:25	14:00	"	95	17	1.0	11	1	P
" "		5	10:40	12:00	"	80	11	1.0	9	1	P

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
Fitzsimmons, C. S.		8 6	11:15	12:30	CWT	75	13	0.9	10	1	P
" "		11	10:40	11:40	"	60	55	1.0	55	1	C
" "			11:45	12:45	"	60	56	1.0	56	1	C
" "			12:50	13:15	"	25	30	1.0	71	1	C
Maine											
Cape Elizabeth											
Dole, R. M.		8 11	8:20	15:20	EST	..	234	0.9	..	1	P
"		13	10:00	13:00	"	180	63	0.7	21	1	P
"		15	11:00	12:00	"	60	17	1.0	17	1	P
Saco											
Graves, Mrs. P. E.		8 9	12:10	13:10		60	26	0.8	26	1	C
"		10	11:40	12:40		60	35	0.7	35	1	C
"		11	12:10	13:10		60	76	0.8	76	1	C
Maryland											
Baltimore											
Crone, L. H.		8 11	11:30	12:00		30	3	1.0	6	1	P
"		12	11:00	12:00		60	2	...	2	1	P
Bestor, O. D.		10	12:30	13:30							
"		11	12:30	13:30		180	2			1	C
"		12	12:30	13:30							
Hochschild, R.	NE	10	10:00	12:00		120	33	1.0	16	1	C
"	NE	11	12:00	13:15		75	81	1.0	65	1	C
Horlock											
Flegal, P. S.	E	8 10	8:45	12:20		?	18	0.6	..	1	D
"	E	11	11:47	12:55		68	31	0.6	28	1	D
Massachusetts											
Oak Bluffs											
Cooke, W.		8 10	10:00	11:30		90	23	1.0	16	1	C
"		11	9:15	10:45		90	75	1.0	50	1	C
Cape Cod											
Kline, H.		8 11	9:45	13:05		200	173	...	52	1	C
"		12	10:00	12:00		120	31	0.7	16	1	C
N. Chatham											
Schermerhorn, Miss H. I.		8 10	14:00	15:00		60	46	...	..	3	C
" "			15:15	15:50		35	10	...	17	1	C
" "		11	10:00	11:15		75	35	...	..	3	C
" "			12:20	14:00		100	35	...	21	1	C
Brockton											
Skinner, G. B.		8 11	8:55	13:50		280	45	0.8	10	1	D
"		13	8:45	10:00		75	5	0.7	4	1	D
Michigan											
Mt. Clement											
Sonnenburg, Miss T.		8 10	12:00	13:00		60	9	1.0	9	1	C
" "			13:00	13:30		30	5	0.5	10	1	C
Mississippi											
Kessler Field											
Graham, Sgt. J. L.		8 10	10:25	11:25		60	6	0.4	6	1	C
" "		11	12:10	13:10		60	40	0.9	40	1	C
" "			13:10	13:20		10	8	0.3	..	1	C
Montana											
Anaconda											
Holderreed, F. L.	N	8 10	15:15	16:15		60	109	1.0	109	1	C
" "	N		16:15	17:15		60	81	1.0	81	1	C
Nebraska											
York											
Megill, Miss E.		8 10	11:15	12:35	CWT	40	14	0.5	21	1	C
Scottsbluff											
Wimmer, Mrs. C. E.		8 10	10:00	10:30		30	15	...	..	5	C
" "		11	10:30	11:00		30	20	0.8	..	5	C
" "			11:00	12:00		60	104	0.8	..	5	C
" "			12:00	12:20		20	28	0.8	..	5	C

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
New Jersey											
Red Bank											
Boyd, R. D.		8 9	10:	11:		60	3	1.0	3	1	C
Paterson											
Chlebnikow, R.		8 10	12:00	13:05		65	11	0.7	10	1	D
Mt. Tabor											
Hutson, D. M.		8 11	13:45	14:15		30	19	...	..	2	C
Hackensack											
Lupton, Dr. and Mrs. B. M.	NW	8 10	12:	13:		60	8	0.5	..	2	C
"	NW	11	12:	13:		60	21	0.5	..	2	C
Ridgewood											
McNaught, Miss M.	NE	8 10	11:08	12:08		60	37	...	..	2	C
Wildwood Crest											
Petaccio, Miss R. E.	NW	8 10	10:	12:		120	15	...	8	1	C
" "	NW	11	11:	12:		60	2	...	2	1	C
" "	NW	12	11:	12:		60	0	...	0	1	C
Denville											
Richardson, Mr. and Mrs. J. A. W.		8 11	12:20	12:50		30	14	...	..	2	C
Ocean City											
Reilly, Miss E. F.		8 11	12:30	14:00		90	14	0.5	10	1	C
Rosengarten, G.		8 10	12:28	14:00	EWT	92	16	...	10	1	C
"		11	13:08	14:08	"	60	31	1.0	31	1	C
"		11	14:08	15:08	"	60	63	1.0	63	1	C
N. Wildwood											
Stolnabb, C. P.	S	8 10	16:15	17:15		60	26	...	26	1	C
Wenonah											
Wakefield, G.	E	8 10	15:30	17:15	EWT	90	28	...	19	1	C
River Edge											
deWolfe, Mr. and Mrs.	N	8 11	11:45	12:45		60	55	...	..	2	C
New York											
Ithaca											
Bates, J.		8 11	11:00	12:33		93	28	0.6	18	1	P
"			12:33	13:24		51	35	0.8	41	1	C
"			13:24	14:20		56	39	0.8	42	1	C
Woodstock											
Mocharniuk, Mr. and Mrs. N.		8 11	15:05	16:05		60	163	1.0	..	2	C
" "			16:35	17:35		60	109	1.0	..	2	C
" "		12	14:10	14:35		25	20	0.4	..	2	C
Bronx											
Orevec, E.		7 7	12:00	16:00	EWT	174	10	0.9	3	1	P
"		8 4	10:32	15:24	"	292	44	0.9	9	1	P
"		10	11:25	13:46	"	141	21	0.5	9	1	P
"		11	9:58	16:38	"	400	130	0.6	19	1	P
Nannet											
Filat, C.		8 11	11:00	11:45		45	14	...	19	1	C
Bronx (Crotona observers)											
Chabot, H.		8 4	9:40	12:46	EWT	186	12	...	4	1	P
"		11	9:59	12:45	"	166	*27*	...	10	1	P
Lochard, I.		7 30	10:00	11:00	"	60	4	0.6	4	1	P
"		8 4	10:30	14:50	"	260	21	0.9	5	1	P
"		11	10:00	13:15	"	195	13	0.4	4	1	P
Brody, P.		7 30	9:41	11:35	"	114	8	0.7	4	1	P
"		8 3	11:25	12:40	"	75	7	0.9	6	1	P
"		4	10:10	13:15	"	185	17	1.0	9	1	P
Rayna, G.		4	10:30	14:50	"	200	19	1.0	6	1	P
"		11	9:45	11:15	"	90	17	0.9	12	1	P
E. White Plain											
Romere, R.		8 11	.....	.....		..	93	...	..	1	C
Geneva											
Smith, C. H.	NE	8 10	11:30	12:00	EWT	30	17	1.0	34	1	C

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
Smith, C. H.	NE	8 10	12:00	13:00	EWT	60	33	...	33	1	C
"	NE	11	14:00	15:00	"	60	25	0.7	25	1	C
"	NE		15:00	16:00	"	60	27	...	27	1	C
Rogers, G.	Z		12:00	13:00	"	60	21	0.7	21	1	C
"	Z		10:30	11:00	"	30	5	0.7	10	1	C
Camp Manhatten											
Taleporos, A.		8 3	12:00	13:34	EWT	94	35	1.0	22	1	D
"		9	11:45	14:00	"	135	60	0.9	27	1	D
New York											
Wilf, H.		8 11	8:40	13:40	EWT	300	30	0.9	6	1	P
Ohio											
Cleveland											
Black, J. L.		8 13	9:00	10:00	EST	60	0	0.4	0	1	C
Rockford											
Russell, O. E.		8 2	12:20	14:25		90	15	0.9	10	1	C
"		3	14:00	15:20		60	11	0.9	11	1	C
"		6	14:35	16:20		60	12	0.6	12	1	C
"		7	13:00	15:25		70	5	1.0	4	1	C
"		8	13:00	14:35		70	6	1.0	5	1	C
"		9	14:00	16:00		120	26	0.9	13	1	C
"		12	15:00	16:00		60	4	0.4	4	1	C
"		13	14:30	15:30		60	5	0.5	5	1	C
Cincinnati											
Wheeler, K. W.		8 10	10:30	11:30		60	15	1.0	15	1	C
"			11:30	12:30		60	25	0.7	25	1	C
Oklahoma											
Norman											
Richardson, N.		7 13	10:10	11:00	CST	60	7	0.7	7	1	P
"		14	11:55	14:55	"	180	34	0.9	11	1	P
"		30	9:35	11:35	"	120	23	0.9	12	1	P
"		8 1	9:55	11:10	"	75	13	0.9	10	1	P
"		2	9:40	11:20	"	100	19	1.0	11	1	P
"		3	9:37	11:10	"	93	20	1.0	13	1	P
"		8	9:38	11:50	"	132	36	1.0	16	1	P
"		9	9:43	12:22	"	159	33	1.0	13	1	P
"		11	9:30	14:50	"	320	185	1.0	35	1	P
Richardson, Mrs. P. H.			9:30	12:30	"	180	125	1.0	42	1	C
Ratcliff City											
Veal, H. K.		8 2	9:40	11:20	CST	100	22	1.0	13	1	P
"		3	9:37	11:10	"	93	24	1.0	15	1	P
"		8	9:38	11:50	"	132	38	1.0	17	1	P
"		9	9:38	11:50	"	132	32	1.0	15	1	P
"		11	9:30	14:50	"	320	163	1.0	31	1	P
Oregon											
Grants Pass											
Bones, J.	NE	8 11	15:30	16:30		60	79	1.0	79	1	C
Gaston, M. C.		8 11	11:	12:30		90	42	...	28	1	C
"		12	10:30	11:30		60	20	...	20	1	C
"		13	14:00	15:00		60	23	...	23	1	C
Eugene											
Bryan, J.		8 11	16:	17:		..	20±0.5		..	1	C
Thompson, Mrs. H.	S	8 12	14:45	15:45	PWT	60	22	0.7	22	1	C
Thompson, Miss B. J.	N		14:45	15:45	"	60	15	0.7	15	1	C
Salem											
Graham, J. W.		8 10	10:15	11:15		60	5	...	5	1	C
"		13	10:25	11:25		60	4	1.0	4	1	C
Silverton											
Jensen, Miss A. K.		8 13	14:15	15:15	PWT	60	31	1.0	31	1	C
"			15:15	16:30	"	75	46	1.0	37	1	C
"		14	15:50	16:50	"	60	24	0.7	24	1	C
"		15	14:18	15:18	"	60	23	1.0	23	1	C
"			15:18	16:18	"	60	39	1.0	39	1	C
"		16	14:13	14:43	"	30	7	0.3	14	1	C

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
"		17	14:14	15:14	"	60	24	1.0	24	1	c
"		18	14:15	15:15	"	60	24	1.0	24	1	c
Princeville											
Van Schoiack, Mr. and Mrs.		8 12	15:	16:		60	50	...	..	2	c
Pennsylvania											
Glenside											
Parkhouse, G.		8 11	11:30	12:30		60	16	...	..	2	c
Wallingford											
Burn, E.		8 11	9:	10:		60	5	...	5	1	p
"			10:	11:		60	13	...	13	1	p
"			11:	12:		60	19	...	19	1	p
"			12:	12:33		33	15	...	27	1	p
Washington Crossing											
Herbert, H. L.		8 10	11:	12:		60	9	0.8	9	1	c
"			12:	13:		60	17	0.8	17	1	c
"			13:	14:		60	26	0.8	26	1	c
"		11	11:20	12:		40	11	1.0	16	1	c
"			12:	13:		60	25	1.0	25	1	c
"			13:	14:		60	32	1.0	32	1	c
"			14:	15:		60	36	1.0	36	1	c
Rose Valley											
Smith, K.	S	8 9	9:	10:		60	14	...	14	1	c
Karsner, J.	N		9:	10:		60	11	...	11	1	c
Karsner, Miss M. A.	E		9:	11:		120	5	...	2	1	c
Karsner, Miss K. H.	W		9:	11:		120	1	...	2	1	c
Karsner, J.	E	8 10	10:	11:		60	8	...	8	1	c
Karsner, Miss M. A.	N		10:	12:		120	22	...	11	1	c
Karsner, Mrs. K. H.	E		10:	12:		120	15	...	8	1	c
Karsner, Miss M. A.	NE		12:	14:		120	57	...	28	1	c
Karsner, Mrs. K. H.	E		12:	14:		120	54	...	27	1	c
Karsner, Miss M. A.	E	8 12	10:	12:		120	27	...	14	1	c
McSherrystown, Krechten		8 11	12:00	12:45		45	31	...	41	1	c
Cook Observatory											
Marshall, R. K.		8 10	11:01	12:00	EST	59	10	...	10	1	c
"			14:00	15:30	"	90	29	...	20	1	c
"		11	10:00	10:30	"	30	6	...	12	1	c
"			12:30	13:30	"	60	19	...	19	1	c
"			13:30	14:30	"	60	25	...	25	1	c
"			14:30	15:30	"	60	25	...	25	1	c
"			15:30	16:00	"	30	3	0.2	..	1	c
Flower Observatory											
Olivier, C. P.	NE	8 9	12:10	13:10	EST	60	10	0.5	10	1	p
"	NE		13:15	14:40	"	90	19	0.8	13	1	p
"	N	10	10:48	11:48	"	60	9	0.6	9	1	p
"	N		11:53	14:25	"	146	26	0.6	11	1	p
"	N	11	11:06	12:06	"	60	15	0.3	15	1	p
"	N		12:06	14:06	"	114	32	0.7	17	1	p
"	N		14:06	14:53	"	47	16	0.5	21	1	p
"	NE	13	11:23	12:30	"	60	8	0.8	8	1	p
Haas, W. H.		11	11:15	13:28	"	133	29	0.5	13	1	p
Schmidt			11:00	13:50	"	170	41	0.5	14	1	p
Heckheimer, C.	N		11:	13:32	"	?	29	0.5	..	1	d
Fairfield											
Roth, D. D.		8 11	11:±	12:35		?	95	0.6	..	4	c
Wilkes-Barre											
Schumanick, A.		8 10	9:00	10:00		60	6	...	6	1	c
"			10:00	11:30		90	23	...	16	1	c
Marietta											
Sebastian, Elder and Mrs. W. H.		8 11	.....	.....		..	12	...	..	2	c

Station and Observer	Dir.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
North Hills											
Shutts, R. V.		8 11	10:52	12:15	EST	83	17	0.5	12	1	P
"			12:25	13:17	"	51	13	0.5	15	1	P
Milton											
Smith, Miss Lois	E	8 11	10:30	11:30	EST	60	4	0.6	4	1	C
"	E	12	11:30	13:00	"	90	16	0.6	11	1	P
"	E		13:	14:30	"	90	33	0.6	22	1	C
"	E		14:30	15:45	"	75	20	0.6	16	1	C
Riegel, Miss E.	N		11:30	13:	"	90	14	0.6	10	1	C
"	N		13:	14:30	"	90	42	0.6	28	1	C
"	N		14:30	15:45	"	75	15	0.6	12	1	C
Martin, R.	NE		11:30	13:00	"	90	27	0.6	18	1	C
"	NE		13:	14:30	"	90	58	0.6	37	1	C
"	NE		14:30	15:45	"	75	17	0.6	14	1	C
Towanda											
VanDerpol, C.	E	8 11	12:45	13:30		45	13	0.5	17	1	D
"	E	12	11:26	12:56		90	31	...	21	1	D
Williamsport											
Wagner, D. H.	N	8 10	10:30	12:00		90	36	1.0	24	1	D
"	NE	11	10:45	12:15		90	44	0.8	30	1	D
Ponco Manor											
*Wildman, E. E.	4Q	8 10	10:45	16:45		360	310	1.0	..	16	C
Gettysburg											
Ziegler, Miss B. A.	N	8 11	12:10	12:40		30	21	...	42	1	C
South Dakota											
Sioux Falls											
Duhon, W. J.	NE	8 11	12:	13:		60	90	...	90	1	C
"	NE		13:	14:		60	105	...	105	1	C
"	NE		14:	15:		60	79	...	79	1	C
Dell Rapids											
Long, Mrs. B.	N	8 10	11:35	13:05		90	20	...	13	1	C
"	N	11	10:00	16:00		360	260	1.0	43	1	C
"	N	13	11:50	12:50		60	14	...	14	1	C
"	N	14	12:15	13:15		60	10	...	10	1	C
"	N	8 11	10:00	16:00		360	290	1.0	48	1	C
Texas											
Kerrsville											
Kemper, Father		8 9	10:30	13:00	CWT	150	9	0.5	4	1	D
Dallas											
Sanders, R.	NE	8 8	13:00	15:00	CWT	120	6	0.4	..	1	P
"	NE	9	13:00	15:00	"	120	36	1.0	18	1	P
"	NE	12	13:00	15:00	"	120	51	1.0	26	1	P
Virginia											
Charlottesville											
*McNeill, W. S.		8 10	12:00	18:00	EWT	360	208	1.0	35	1	C
"		11	12:00	18:00	"	360	276	1.0	46	1	C
"		12	12:00	18:00	"	360	154	0.8	26	1	C
Limeton											
McWilliams, J.		8 10	11:15	11:45		30	7	...	14	1	C
"		11	10:	11:30		90	2	...	..	1	C
"		12	10:	12:		90	12	...	8	1	C
Washington											
Pullman											
Bidlake, Miss M.		8 9	10:	12:		120	69	...	34	1	C
"		10	11:	13:		120	19	...	10	1	C
"		12	10:	14:		240	222	...	56	1	C
"		13	10:	14:		240	233	...	58	1	C
Pasco											
Oberst, W.		8 11	11:	12:	PWT	60	56	...	56	1	C
Seattle											
Parmenter, B. C.		8 9	9:30	14:30	PWT	..	32	0.7	..	1	P

Station and Observer	Div.	Date	Began	Ended	Time	Min.	Met.	Fac.	R.	Ob.	C
Clinton											
Thorsheim		8 9	10:	10:40		40	19	...	29	1	c
"		10	10:	10:40		40	3	...	4	1	c
"		11	10:	10:40		40	30	...	45	1	c
"		17	10:	10:40		40	3	...	4	1	c
Wisconsin											
Slinger											
Brooks, C. H.	NE	8 11	10:45	13:00		45	14	...	19	1	c
"	NE		13:30	14:05		30	21	...	42	1	c
"	NE		15:45	16:15		30	15	...	30	1	c
"	NE	12	12:45	14:50		40	15	...	22	1	c
Milwaukee											
Halbach, Mr. and Mrs. E. A.		8 12	13:05	15:07	CWT	122	18	0.5	..	2	P
Miller, R.			13:05	14:05	"	60	32	0.5	32	1	c
"			14:07	15:07	"	60	18	0.5	18	1	c
		1944									
New Jersey											
Titusville											
McKeon, Mrs. J. J.		8 8	8:50	10:10	EST	?	6	0.9	..	1	P
"		9	9:00	9:35	"	?	6	0.5	..	1	P
"		10	9:00	11:15	"	135	35	0.7	16	1	P
"		12	8:00	15:50	"	470	45	0.5	6	1	P
"		14	8:30	9:45	"	75	8	0.7	6	1	P
"		8	8:30	10:10	"	100	8	0.9	5	1	P
"		10	9:15	10:04	"	?	11	0.7	5	1	P
Total . . .						13,245					

Flower Observatory, Upper Darby, Pa., 1945 October 11.

Contributions of the Society for Research on Meteorites

Edited by **FREDERICK C. LEONARD**
Department of Astronomy, University of California, Los Angeles 24

Studies of the Meteoritic Falls of the World: 6. Doubtful and Duplicate Falls and Falls Having Uncertain and Intermediate Classifications[1]

FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles

ABSTRACT AND INTRODUCTION

This paper contains an alphabetical list of classificational symbols for meteorites (Table 1) and a compilation of all the (*i*) falls of doubtful authenticity (Table 2); (*ii*) duplicate and possibly duplicate falls (Table 3); (*iii*) falls having uncertain classifications (Table 4); and (*iv*) falls having intermediate or plural classifications (Table 5) that are recorded in A. L. Coulson's "A Catalogue of Meteorites," *Memoirs of the Geological Survey of India*, **75**, 1940. Each group of falls is commented on briefly.

In Table 1, the names of the principal divisions and subdivisions of meteorites (*e.g., aerolite* and *achondrite*) are italicized. It should be observed that while most of the symbols in this table are identical with those in the "List of Symbols," Ch. 2, pp. 16-18, of Coulson, some of them differ from the corresponding ones in that list.

In Tables 2-5, the complete geographical name of each included fall is given in the first column; its provisional coördinate number[2] in the second; its classification (for key, see Table 1) in the third; and the time of fall, find, or recognition, in the fourth. Table 3 carries also a fifth column headed "Remarks." An asterisk affixed to the name of a fall calls attention to a note on it at the end of the table. Nearly all of the information presented in the first, third, and fourth columns of each table and in the fifth column of Table 3 has been taken from Coulson, while the provisional coördinate numbers in the second column have been copied from our manuscript catalog of the meteoritic falls of the world. Since these numbers are subject to correction in many cases, they should all be regarded as provisional. Numbers concerning which there is considerable uncertainty are followed by a colon (:). The times in the fourth column are *civil* times, reckoned from 0^h (midnight) to 24^h. The following abbreviations are employed in these tables: ab. = about; be. = before; cl. = classification; fd. = found; fl. = fell; id. = identical; kn. = known; P.C.N. = provisional coördinate number; poss. = possibly; prob. = probably; and re. = regarding.

While most of the falls enumerated in the accompanying tables should be carefully investigated, it would be advantageous, probably in statistical discussions at least, to disregard all those of Table 2, except Minas Geraes, Brazil, of which only the place seems to be in doubt. It is questionable whether any useful purpose would be served by including any of the 15 falls of Table 2, of doubtful authenticity, in any future catalog, unless, meantime, the doubt should be removed.

In determining which falls of Table 3 are duplicates, investigators will have to exercise their own judgment in the large majority of cases and decide each case on its own merits.

Definitive information concerning the classification, not only of the 32 falls of Table 4 but also of the several falls of unknown classification and the many falls "not further classified," which are assembled in Ch. 5, pp. 232-79, of Coulson, is badly needed.

As for the falls of Table 5: it is quite to be expected that a number of falls should prove to have "intermediate" classifications; the surprising thing is that not more of them do. The few falls having "plural" classifications deserve critical study to determine whether they were correctly classified originally and, if so, whether they are just "intermediates" or true "composites"—*i.e.*, falls exhibiting the characters of 2 or more distinct classes.[3]

Notes and References

[1] "Statistical Studies of the Meteoritic Falls of the World: 5. The Observed Sideritic and Siderolitic Falls" appeared in *C.S.R.M.*, **3**, 73-8; *P.A.*, **51**, 161-7, 1943.

[2] For the definition of the term "coördinate number" and a detailed discussion "On the Assignment of Coördinate Numbers to Meteoritic Falls," see F. C. Leonard, *C.S.R.M.*, **3**, 153-5; *P.A.*, **52**, 306-7, 1944, and the other sources referred to in that paper.

[3] Some of the specimens of the Brenham Twp., Kiowa Co., Kansas, fall (P.C.N. = 0992,376; fd. 1882) show a remarkable combination of both pallasitic and octahedritic features (see Fig. 13, opp. p. 34, of H. H. Nininger's *Our Stone-Pelted Planet*, 1933); the classification of these "composite" specimens might well be expressed as "PK + O."

TABLE 1. ALPHABETICAL LIST OF CLASSIFICATIONAL SYMBOLS FOR METEORITES

A, *aerolite;* Ac, *achondrite;* Am, amphoterite; An, angrite.

Bu, bustite.

C, *chondrite;* Ca, veined chondrite; Cb, brecciated chondrite; Cc, spherical chondrite; Cca, veined spherical chondrite; Ccb, brecciated spherical chondrite; Cck, crystalline spherical chondrite; Ccka, veined crystalline spherical chondrite; Cckb, brecciated crystalline spherical chondrite; Ccn, ngawite; Cco, ornansite; Cek, crystalline enstatite-anorthite-chondrite; Cg, gray chondrite; Cga, veined gray chondrite; Cgb, brecciated gray chondrite; Cha, chassignite; Chl, chladnite; Chla, veined chladnite; Cho, howarditic chondrite; Choa, veined howarditic chondrite; Ci, intermediate chondrite; Cia, veined intermediate chondrite; Cib, brecciated intermediate chondrite; Ck, crystalline chondrite; Cka, veined crystalline chondrite; Ckb, brecciated crystalline chondrite; Co, orvinite; Cs, black chondrite; Csa, veined black chondrite; Ct, tadjerite; Cw, white chondrite; Cwa, veined white chondrite; Cwb, brecciated white chondrite.

D, *ataxite;* D_1, nickel-rich ataxite; D_1B, nickel-rich ataxite, Babb's Mill group; D_1C, nickel-rich ataxite, Cape group; D_1L, nickel-rich ataxite, Linville group; D_1Sh, nickel-rich ataxite, Shingle Springs group; D_2, nickel-poor ataxite; D_2b, brecciated nickel-poor ataxite; D_2N, nickel-poor ataxite, Nedagolla group; D_2P, nickel-poor ataxite, La Primitiva group; D_2S, nickel-poor ataxite, Siratik group; D_2T, nickel-poor ataxite, Tucson group; D_3, intermediate ataxite.

Eu, eukrite.

H, *hexahedrite;* Ha, granular hexahedrite; Hb, brecciated hexahedrite; Hn, normal hexahedrite; Ho, howardite; Hob, brecciated howardite.

K, carbonaceous chondrite; Kc, spherical carbonaceous chondrite; Kca, veined spherical carbonaceous chondrite.

Li, *lithosiderite;* Lo, lodranite.

Mi, *meteorite;* Ms, mesosiderite; Msg, mesosiderite, grahamite.

O, *octahedrite;* Ob, brecciated octahedrite; ObC, brecciated octahedrite, Copiapo group; ObK, brecciated octahedrite, Kodaikanal group; ObN, brecciated octahedrite, Netschaëvo group; ObZ, brecciated octahedrite, Zacatecas group; ObZG, brecciated octahedrite, Zacatecas-N'Goureyma group; Of, fine octahedrite; Off, finest octahedrite; Offa, granular finest octahedrite; Offb, brecciated finest octahedrite; OfV, fine octahedrite, Victoria group; Og, coarse octahedrite; Ogg, coarsest octahedrite; OH, octahedrite, Hammond group; Om, medium octahedrite.

P, pallasite; PB, pallasite, Bitburg group; PI, pallasite, Imilac group; PK, pallasite, Krasnojarsk group; PR, pallasite, Rokicky group.

Ro, rodite.

Sa, *siderœrolite;* She, sherghottite; Si, *siderite;* So, *siderolite;* Sy, siderophyre.

Ur, ureilite.

Wht, whitleyite.[1]

NOTE TO TABLE 1

[1] A more appropriate name for this class might be "cumberlandite," symbol, "Cu," the archetype (and only known example up to date) being Cumberland Falls, Whitley County, Kentucky (P.C.N. = 0842,367:; fl. 1919 Apr. 9, "noon").

TABLE 2. DOUBTFUL FALLS

NAME	P.C.N.	CL.	TIME
Alwal, near Hyderabad, Hyderabad State, India*	*0785*,174	Si?	"Fl. ab. 1901, just be. dawn"
Amun, Thebes, Egypt	*0314*,300:	Si	"Kn. for centuries"
Angara, Yeniseisk, Siberia, U.S.S.R.	*1034*,530:	Si	Fd. 1885
Atsuma-Mura, Yūfutsu, Hokkaido, Japan	*1425*,438:	Mi	Fl. 1935 Sep. 3
Fairplay, Missouri	0934,376:	Ms	Fd. 1903
Gao, French W. Africa	*0003*,162:	Mi?	Fl. 1932 Jan. 19, 21^h
Glen Osborne, S. Australia	*1350*,306:	Mi?	Kn. 1927
Hanau, Hesse-Nassau, Germany	*0089*,502	A	Fl. 1877 Aug. 21
Ipacaray Lake, Paraguay	0573,*253*	A?	Fl. be. 1877
Langeac, Auvergne, France*	*0035*,451	Mi	Fl. 1900 Aug. 13
Le Gould's Stone, Leichardt Dist., Queensland, Australia	*1489*,*237*:	A	Fd. be. 1864
Minas Geraes, Brazil*	0440,*183*:	Cwa	Kn. 1888
Mordan, New S. Wales, Australia	*1424*,*305*	Si?	Kn. 1927
Ponta Grossa, Parana, Brazil*	0504,*251*	A?	Fl. 1846 Apr.
Rheinpfalz, Germany	*0115*,481:	Mi	Fl. 1932 July 19, 3^h 36^m
Thangoo, Western Australia*	*1224*,*182*	Mi	Fl. 1936 June 15, 7^h 10^m

NOTES TO TABLE 2

Alwal: See M. A. R. Khan, *C.S.R.M.*, **1**, No. 2, 57-60; *P. A.*, **44**, 565-8, 1936.
Langeac: No further information.
Minas Geraes: Place only, in doubt.
Ponta Grossa: "Pseudometeorite?"
Thangoo: No further information.

TABLE 3. DUPLICATE AND POSSIBLY DUPLICATE FALLS

NAME	P.C.N.	CL.	TIME	REMARKS
Accalana, S. Australia	*1334,260*:	Mi	Fd. be. 1917	"Poss. same as Carraweena & Artracoona"
Alice Springs, MacDonnell Ranges, Cent. Australia	*1339,236*	P: PR?	Fd. 1924	"Prob. includes Huckitta"
Altonah, Duchesne Co., Utah	1102,404	Si	Fd. ab. 1932	"Poss. same as Duchesne Co."
Arabia	*0464,245*:	Mi	Kn. be. 1931	"Prob. Hedjaz"
Artracoona, Cent. Australia	*1400,291*:	Cs	Fd. 1914	"Poss. same as Accalana & Carraweena"
Barraba, Darling Co., New S. Wales, Australia	*1506,304*	D_2	Fd. be. 1904	"Poss. the same as Bingera & Warialda"
Bear Creek, Jefferson Co., Colorado	1053,396	Of	Fd. 1866	Jefferson prob. id. with it
Bingera, Murchison Co., New S. Wales, Australia	*1506,299*	D_2	Fd. 1880	"Poss. same as Barraba & Warialda"
Caparrosa, s.w. of Chilpanzingo, Guerrero, Mexico	1000,174:	Si	Kn. 1858	"Prob. Toluca" = Xiquipilco, *q.v.*
Carraweena, S. Australia	*1400,292*	C	Fd. 1914	"Poss. the same as Accalana & Artracoona"
Cartoonkana, New S. Wales, Australia	*1323,200*:	A	Fd. 1914	"Poss. Yandama"
Cobija, Pampa of Santa Barbara, Antofagasta, Chile	0704,*236*	Ck	Fd. 1892	Lampa "most prob." id. with it
Copiapo, Atacama, Chile	0693,*272*	ObC	Fd. 1863	Corrizatillo poss. id. with it
Corrizatillo, Copiapo, Atacama, Chile	0702,*272*	Si	Kn. 1884	"Poss. Copiapo"
Duchesne Co., Utah	1104,402	Of	Fd. 1906; fl. 1896 July 5?	Altonah prob. id. with it
Durango, Mexico	1046,240	Mi	Fd. 1904?	"Ward's mss., poss. Morito or Rancho de la Pila"
Hedjaz, Arabia	*0360,260*:	Cg	Fl. 1910, "spring night"	Arabia prob. id. with it
Huckitta Station, 135 mi. n.e. of Alice Springs, Cent. Australia	*1323,200*:	P: PI?	Fd. 1937 July	"Poss. id. with Alice Springs"
Jefferson, 30 mi. from Denver, Colorado	1053,396:	Si	Fl. 1867 June	"Prob. Bear Creek"
Kadonah, Agra Dist., United Prov., India	*0783,271*	Cga	Fl. 1822 Aug. 7, "night"	Kandahar prob. id. with it; see Coulson, pp. 114-15 & 116-17.
Kandahar, India	*0772,189*	A?	Fl. 1833, "end of Nov."	Prob. id. with Kandonah; see ref. under that fall, *ante.*
Kanzaki, Hizen, Japan	*1354,348*	A	Kn. 1906	"Poss. Kyushu"
Kingoonya, Nullarbor Plain, S. Australia	*1354,309*	C	Fd. be. 1927	"Poss. same as Lake Labyrinth"

TABLE 3. DUPLICATE AND POSSIBLY DUPLICATE FALLS (CONTINUED)

TABLE 3. DUPLICATE AND POSSIBLY DUPLICATE FALLS (CONTINUED)

NAME	P.C.N.	CL.	TIME	REMARKS
Kyushu, Japan	*1310,323*:	Cwa	Fl. 1886 Oct. 26, 15^h	Kanzaki prob. id. with it
Lake Labyrinth, S. Australia	*1350,306*:	Cgb	Fl. 1924 Feb. 5, "night"? Fd. 1934 Oct.	Kingoonya prob. id. with it
Lampa, Sierra de Chicauma, Atacama, Chile	0709,*332*	Ck	Fd. be. 1905	"Most prob. is Cobija"
Mejillones, Atacama, Chile (1875)	0705,*230*	Hb	Fd. be. 1875	Mejillones (1905) poss. id. with it
Mejillones, Atacama, Chile (1905)	0705,*230*	D_2N	Fd. 1905 May; "label stated fl."	"Poss. same as [Mejillones] 1875"
Morito, San Gregoria, Chihuahua, Mexico	1057,279	Om	Kn. 1600	Durango poss. id. with it or with Rancho de la Pila
Mount Joy, Adams Co., Pennsylvania	0772,398	Ogg	Fd. 1887	"Poss. Pittsburgh"
Nativitas, Zaragoza Dist., Tlaxcala, Mexico	0991,192	Om	Fd. 1904	"Most prob. Santa Apolonia"
Nejed, Wadee Banee Khaled, Cent. Arabia	*0430*,254	Om	Fd. 1863	"Poss. Wabar"
New Baltimore, Somerset Co., Pennsylvania	0788,400	Ogg	Fd. 1922	"Poss. Pittsburgh"
Pittsburgh, Allegheny Co., Pennsylvania	0800,405	Ogg	Fd. ab. 1850	"Poss. includes Mount Joy & New Baltimore"
Rancho de la Pila, Durango, Mexico	1046,240	Om	Kn. 1804	Durango poss. id. with it or with Morito
Santa Apolonia, Tlaxcala, Mexico	0982,192	Om	Fd. 1872	Nativitas prob. id. with it
Siena, Tuscany, Italy	*0114*,433	Ci-Cho	Fl. 1794 June 16, 19^h	Tiree poss. id. with it
Tenham Station, S. Gregory, Queensland, Australia	*1427,255*	Cwb-Cwa	Fl. 1869 Feb., "night"	Warbreccan "most prob. id with" it
Tiree, Hebrides, Scotland	0068,565	Ci	"Labelled (? fl.) 1808"	"Poss. is Siena"
Valley Wells, San Bernardino Co., California	1157,355	Cg	Fd. 1929 June 10	Windmill Station id. with it; see F. C. Leonard, *C.S.R.M.*, **3**, 174-5; *P. A.*, **52**, 513-14, 1944.
Wabar, Rub' al Khali, Arabia	*0507*,215	Om	Fd. 1932 Feb.	Nejed poss. id. with it
Warbreccan Run, Windorah, Grey Co., Queensland, Australia	*1428,243*	Cwa	Kn. be. 1904	"Most prob. id. with Tenham"
Warialda, Burnett Co., New S. Wales, Australia	*1506,296*	D_2 or H?	Fd. 1919	"Poss. the same as Barraba & Bingera"
Windmill Station, San Bernardino Co., California	1157,355	Mi	Fd. 1929	Id. with Valley Wells; see ref. under that fall, *ante*.
Xiquipilco = Toluca, Mexico State, Mexico	0997,194	Om	Kn. be. 1776	Caparrosa prob. id. with it
Yandama, near border with S. Australia, New S. Wales, Australia	*1415,296*	C	Kn. be. 1927	"Poss. Cartoonkana is id."

TABLE 4. FALLS HAVING UNCERTAIN CLASSIFICATIONS

NAME	P.C.N.	CL.	TIME
Alice Springs, MacDonnell Ranges, Cent. Australia	*1339,236*	P:PR?	Fd. 1924
Barratta, Deniliquin, Townsend Co., New S. Wales, Australia	*1146,353*	Cs or Ci?	Fd. 1845
Baxter, Stone Co., Missouri	0935,366	A: Cg?	Fl. 1916 Jan. 18, 9^h
Bear Lodge, Weston Co., Wyoming	1042,438:	Si: O?	Fd. 1931, "summer"
Beverbruch, Cloppenburg, Oldenburg, Germany	*0082*,531:	A: Cg?	Fl. 1930 Sep. 10, 14^h 15^m
Bridgewater, Burke Co., North Carolina	0819,357	Of or Om?	Fd. 1890
Chihuahua City, Chihuahua, Mexico	1061,286	Si: Offb?	Kn. 1929; fd. 1907?
Constantia, near Cape Town, S. Africa	*0271,295*	A: Cw?	Fl. 1906 Nov. 4?, 16^h 30^m
Crescent, Logan Co., Oklahoma	0976,360	A: K?	Fl. 1936 Aug. 17, 19^h 07^m
Fayetteville, Washington Co., Arkansas	0942,361	A: C?	Fl. 1934 Dec. 26, ab. 11^h 58^m
Garraf, Barcelona, Catalonia, Spain	*0021*,412:	A: Cw?	Fd. 1905
Huckitta Station, 135 mi. n.e. of Alice Springs, Cent. Australia	*1323,200*:	P: PI?	Fd. 1937 July
Karoonda, Buccleugh Co., S. Australia*	*1399,351*	Cc or Cha?	Fl. 1930 Nov. 25, 22^h 53^m
Kukschin, Chernigov Region, Ukraine, U.S.S.R.	*0318*,510	A: Cg?	Fl. 1938 June 11, 14^h
Kurumi, near Miki, n.w. of Kobe, Japan	*1305*,333	C: Cg?	Fl. 1930 May 27, "ab. noon"
Lafayette, Colorado*	1051,400	Si: D_4?	Fd. be. 1908
Lafayette, Indiana	0869,404	Ac: An?	Kn. 1931
La Rinconda, Sevilla, Spain	0060,374:	Li: P?	Fl. 1934 July 17
Lujan, Buenos Aires, Argentina	0592,*345*	Sa: Ms?	Fd. be. 1892
Lyubimovka, Mikhailov Dist., Dnepropetovsk Region, Ukraine, U.S.S.R.	*0392*,542:	Am or Eu?	Fl. 1936 Apr. 2, 1^h
Meester-Cornelis, Batavia, Java*	*1069,062*	C: Cg?	Fl. 1915 June 2, 6^h 15^m
Myhee Caunta, Mahi Kantha State, Bombay, India*	*0726*,230	A: Ci?	Fl. 1842 Nov. 30, 16^h
Naretha, Western Australia	*1244,307*	A: Cg?	Fd. 1915
Näs, Värvik, Dalsland, Sweden	*0180*,593	A: Cg?	Fd. 1907
Prambachkirchen, Eferding, Upper Austria*	*0140*,483	C: Cw?	Fl. 1932 Nov. 5, 21^h 55^m 57^s
Shirohagi, Etchu, Japan	*1372*,364:	Si: O?	Fd. 1890
Simondium, Lower Paarl, Cape Prov., S. Africa	*0186,334*:	A: Ho?	Fd. 1907
Tanezrouft, Western Sahara, Algeria*	*0005*,240:	Cg or Ck?	Fd. 1936 Feb.
Tysnes Is., Hardanger Fiord, Norway*	*0056*,600	Cgb or Cib?	Fl. 1884 May 20, 20^h 30^m
Umm Tina, Rub' al Khali, Arabia*	*0510*,200:	C: Cw?	Fd. 1932 Feb. 20
Warialda, Burnett Co., New S. Wales, Australia	*1506,296*	D_3 or H?	Fd. 1919
Western Arkansas, Arkansas	0922,347:	Si: D_3?	Fd. be. 1890 June

NOTES TO TABLE 4

NOTES TO TABLE 4

Karoonda: See Coulson, p. 118, re. cl.
Lafayette, Colorado: See G. T. Prior's *App. Cat. Mi., Brit. Mus. (Nat. Hist.)*, p. 26, 1927.
Meester-Cornelis: See Coulson, p. 145, re. cl.
Myhee Caunta: See Coulson, p. 156.
Prambachkirchen: See Coulson, p. 179, re. cl.
Tanezrouft: See Coulson, p. 209, re. cl.
Tysnes: See Coulson, p. 217, re. cl.
Umm Tina: See Coulson, p. 218, re. cl.

TABLE 5. FALLS HAVING INTERMEDIATE OR PLURAL CLASSIFICATIONS

NAME	P.C.N.	CL.	TIME
Cranganore, Cochin State, India	*0763*,102	Cg-Cw	Fl. 1917 July 3, $12^h\ 45^m$
Delegate, Wellesley Co., New S. Wales, Australia	*1490*,370	Om-Og	Fd. ab. 1904
Dokachi, Munshiganj Subdiv., Dacca Dist., Bengal, India	*0903*,235	Ci-Cia	Fl. 1903 Oct. 22, 19^h
Dungannon, Scott Co., Virginia	0824,368	Om-Og	Fd. 1922-23
Garhi Yasin, Shikarpur taluq, Sukkur Dist., S. India	*0685*,279	Om-Og	Fl. 1917 Jan. 7-15, "night-time"
Gerona, Catalonia, Spain	*002*8,420	Cgb-Cwb	Fd. 1899
Goose Lake, Modoc Co., California*	1205,420	Om-Og	Fd. 1938 Oct. 13
Gundaring, Western Australia	*1213,246*:	Og-Ogg	Fl. 1930 Apr. 6, 14^h? Fd. 1937 May
Haraiya, 14 mi. w. of Basti, Basti Dist., United Prov., India*	*0825*,268	Cw-Cg	Fl. 1878 Aug. or Sep.
Indian Valley Twp., Floyd Co., Virginia*	0805,369	D_3b-Hb	Fd. 1887
Kikino, Vyazma, Smolensk, Russia, U.S.S.R.	*0343*,552	Cg-Cw	Fl. 1809
Laborel, Drôme, France	*0052*,444:	Ci-Cib	Fl. 1871 June 14, 20^h
Mirzapur, Saidpur tahsil, Ghazipur Dist., United Prov., India	*0832*,257	Cia-Cib	Fl. 1910 Jan. 7, $11^h\ 30^m$
Ness Co., Kansas*	0996,385	Ck-Cib	Fd. 1894
Ojuelos Altos, Fuente Ovejuna, Cordoba, Spain*	*0055*,382	Ca-Cb	Fl. 1926 Dec. 10, $9^h\ 30^m$
Olmedilla de Alarcón, Cuenca, Spain	0039,418	Cwb-Cwa-Eu	Fl. 1929 Feb. 26, "ab. midday"
Persimmon Creek, Cherokee Co., North Carolina*	0841,351	Offa; Ob; Offb-P	Fd. 1903

TABLE 5. FALLS HAVING INTERMEDIATE OR PLURAL CLASSIFICATIONS (CONTINUED)

NAME	P.C.N.	CL.	TIME
Plainview, Hale Co., Texas*	1016,342	Cia-Cc	Fd. 1917
Quartz Mountain, Nye Co., Nevada*	1167,372	Si: Og	Fd. 1935 Apr. 24
Quinn Canyon, Nye Co., Nevada*	1154,381	Om-Og	Fd. 1908
Rancho de la Presa, Zenapecuaro, Michoacan, Mexico*	1020,191:	Cgb-Cga-Cc	Fl. 1899
Rodeo, Durango, Mexico*	1047,253	Of-Om	Fd. 1852
Santa Rosa, Tunja, Boyaca, Colombia*	0739,056	D_2S-Ob	Fd. 1810
Siena, Tuscany, Italy	*0114,433*	Ci-Cho	Fl. 1794 June 16, 19[h]
Tenham Station, S. Gregory, Queensland, Australia*	*1427,255*	Cwb-Cwa	Fl. 1869 Feb., "night"
Tieraco Creek, N. Murchison Goldfield, Western Australia	*1190,272*:	Of-Om	Fd. be. 1922
Vaalbult, Prieska Div., Cape Prov., S. Africa	*0225,294*:	Og-Ogg	Fd. be. 1918 Apr. *22*
Youndegin, Avon, S.W. Div., Western Australia	*1174,317*	Og-Ogg	Fd. 1884

NOTES TO TABLE 5

Goose Lake: Altho this fall is not listed in Coulson, it is here included for the sake of completeness; see F. C. Leonard, *C.S.R.M.*, **2**, 145-6; *P. A.*, **47**, 507-8, 1939.

Haraiya: See Coulson, p. 101.

Indian Valley: See Coulson, p. 108, re. cl.

Ness Co.: "Classed as Cib by Ward."

Ojuelos Altos: See Coulson, p. 166, re. cl.

Olmedilla: See Coulson, p. 166, re. cl.

Persimmon Creek: See Coulson, p. 173, re. cl.

Plainview: "Cc according to Merrill."

Quartz Mountain: Cl. given only as Si in Coulson; see F. C. Leonard, *C.S.R.M.*, **3**, 173-4; *P. A.*, **52**, 512-13, 1944.

Quinn Canyon: Cl. given as Om in Coulson and as Og by Leonard: see ref. under "Quartz Mountain," *ante*.

Rancho de la Presa: "Cc according to Ward"; according to H. H. Nininger (*C.S.R.M.*, **3**, 37-8; *P. A.*, **50**, 388-9, 1942), the cl. is prob. Cgb-Cga.

Rodeo: "Om according to Farrington."

Santa Rosa: See Coulson, p. 192, re. cl.

Tenham: See Coulson, p. 210, re. cl.

President of the Society: LINCOLN LA PAZ, Department of Mathematics and Institute of Meteoritics, University of New Mexico, Albuquerque
Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, P. O. Box 9866, Los Feliz Station, Los Angeles 27, California

Comet Notes

By G. VAN BIESBROECK

Last month has gone by without additions to the comets observable at this time. Only PERIODIC COMET KOPFF (1945 *b*) remains in reach of moderate-sized telescopes. As foreseen, it gradually loses in brightness as the distance increases. I called the magnitude 10½ on October 3 when the comet showed a well-defined nucleus in the center of a round coma gradually fading to a diameter of about 4′. No trace of a tail could be recognized.

This object has now been under observation for five months. With larger instruments it could readily be followed for a couple of months more although the decreasing altitude will make observations less easy toward the end of the year.

COMET VÄISÄLÄ (1944 *b*) remains faint but can still be followed for some time. On October 10, I estimated the magnitude at 15. This periodic object differs much in appearance from COMET KOPFF. In this case almost all the light is concentrated in a nucleus of some 8″ in diameter, rather sharply defined. There is, however, an extremely faint coma extending to a diameter of about 30″ around this nucleus. On short exposures the comet can hardly be distinguished from an asteroid.

Plates taken of the field of COMET SCHWASSMANN-WACHMANN (1925 II) on October 10 have not shown anything cometary there brighter than magnitude 17. Ephemerides for this curiously variable object have been provided independently by P. Herget (Washington) and J. G. Behrens (Detern) with practically identical results so that there cannot be much uncertainty as to the location. The region should be carefully watched for the recurrence of outburst of brightness.

Williams Bay, Wis., October 15, 1945.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

The Line of Reality

The mind deals with entities; that is, with things which have reality and distinctness of being in fact. So long as it deals with such subjects, reason appears to be on firm ground; when it encounters non-entities, it slips. An entity, as we have defined it, is something tangible, visible, or otherwise real, in the meaning that it can, in a direct or indirect way, affect the senses, and thus convince us of its reality.

On the basis of this definition, matter in any form is an entity; energy in many of its forms is also an entity. These things may be touched, or felt, or seen, either directly or through instruments.

Let us take some matter, which is undoubtedly an entity. Let us convert that matter, as it is theoretically (and to some extent practically) possible to do, into a corresponding quantity of energy. The conversion will proceed in accordance with Einstein's famous equation $E = Mc^2$, where E is the energy produced in ergs, M the mass in grams, and c the velocity of light in centimeters per second.

Energy may readily be converted into various forms. Let us take the energy that has been created by the annihilation of the original matter, and convert it into mechanical energy, which we employ in raising to the top of its case, the weight in a grandfather clock. When the energy has been used up in this operation, it becomes, we say, "potential energy" or energy of position. Now, potential energy, though mathematically equivalent to the particular quantity of that form of energy from which it was converted, is peculiar in this way: it is a non-entity. It is merely the space coordinates of a mass in a gravitational field, which is a pure abstraction and not an entity at all. Though we test the clock weight with every resource of science, we shall find no sensible energy in it; we shall find no difference of any kind at the top of the clock case and at the bottom, except the difference in position. The energy, as an entity, has disappeared. In other words, we have taken a mass of matter—a pure entity—and through a series of transformations, we have destroyed the "reality" of that matter, leaving in its place only a mathematical abstraction.

That we may reconvert this abstraction again into an entity—into heat, perhaps, which will warm our hands, by allowing the clock weight, attached to suitable apparatus, to descend in its case—merely proves that the line between reality and abstraction is as easily passed in one direction as in the other.

Perhaps we will be wise to realize that the things that the mind calls "real" may be only a facet of a hidden basis of reality forever out of our reach and beyond our reason. The mind is a specialized instrument, adapted to deal with sense-experience, and utterly helpless and unreliable when applied to matters beyond that limited horizon.

PAUL E. WYLIE.

2319 St. George Street, Los Angeles, California, August 13, 1945.

General Notes

Sterling Bunch—an Appreciation

[In the preceding issue was given the information that Mr. Sterling Bunch, an amateur astronomer of Fort Worth, Texas, had died on July 13, 1945, at the age of 45. EDITOR.]

Only once, I think, did I ever see Sterling Bunch face to face; yet for years I was sure I knew him better than many with whom I had frequent and intimate personal contacts. When just a boy, eight years old, he wrote a little article for the "Children's Page" of the weekly religious paper I edited. It was so exceptional for one so young that I sent him a letter, thus starting a correspondence which continued far into his manhood—until I retired.

Through his writings, I saw his development and ideals, and often recalled

Longfellow's brilliant observation that a "boy's thoughts are long, long thoughts." But the rest of the familiar quotation—"a boy's will is the wind's will"—seemed not to apply to Sterling; his will seemed to move steadily with his thoughts, illustrating Bulwer-Lytton's conclusion that "thought is valuable in proportion as it is generative."

His opportunities were very limited in boyhood and he worked hard; but in all this he developed the qualities of idealism, fidelity, and perseverance which manifested themselves all through his life and held the confidence and esteem of all who knew him. Sometimes, after all, what we call "disadvantages" seem to count more in high and fine development than all of the aid which can be given.

"Why"—loved ones ask—"why is a life of this type cut off after but few years of manhood?" No one knows the answer positively, but it seems rather clear that there are some who live more of a full, rich life within a few decades than do others who continue existence on earth for close to a century. Was it Young who wrote, "We measure life by tears, not years"? At any rate, some compress more of true living into a comparatively few years of thought and struggle than others ever do. To live long is not so important as to live fully. Sterling Bunch lived a full, a useful, a commendable life—and now lives it more fully.

JAS. E. CLARKE.

920 Benton Avenue, Nashville 4, Tenn.

The Cleveland Astronomical Society

The 1945-1946 program of the Cleveland Astronomical Society was opened on October 12, by a lecture on "Atomic Energy Producing the Light and Heat of the Sun." Dr. J. J. Nassau, director of the Warner and Swasey Observatory and president of the society, was the speaker. His two heroes for the evening were the sun and the atom.

The sun was described as to its composition, state of matter, temperature, pressure, and age. Temperatures in the interior may exceed 20 million degrees C. Pressures in the interior may reach 10 million times that of the atmosphere on the earth. Geological evidence indicates that the earth is probably at least two billion years old. The sun must be at least that old.

The speaker reviewed briefly the early speculations to account for the light and heat of the sun, such as combustion, gravity-contraction, and atomic energy. At this point the speaker introduced his second hero, the atom. In order to give the audience an idea of the size of an atom he made this comparison: an apple is as much larger than an atom as the earth is larger than an apple. The names, masses, and electric charges of the constituent parts of the atom were given. The atoms of several elements were then described. Gum drops were used as the constituent particles in building up the nuclei of some of these. Isotopes may be formed by adding neutrons to the nucleus of the normal element. These isotopes are usually unstable. The isotope Uranium 235 was given as an example. When the nucleus of this atom is struck by a neutron it breaks up to form barium and krypton which in turn are unstable and give off their neutrons, which bombard more uranium atoms. This is what takes place in the atomic bomb.

Some similar reaction of unstable atoms may be responsible for the energy radiated from the sun. The speaker placed on the blackboard a chain of six reactions starting with carbon and hydrogen and ending up with carbon and helium. During these reactions only hydrogen was used up and gamma rays were emitted.

These gamma rays or x-rays which develop in the sun's interior are changed to ordinary rays on their way out to the surface. It has been computed that for each second 564 million tons of hydrogen are changed to 560 million tons of helium by these reactions. This leaves a loss of four million tons of matter per second which is assumed to be changed to energy. Hydrogen acts as the fuel and helium is the ash in the generation of energy. The sun's mass is believed to consist of about 35 per cent of hydrogen, therefore plenty of fuel is available. At the rate indicated above less than one per cent of the mass of the sun would be used up in two billion years, the minimum age of the sun. These reactions among unstable atoms may also be responsible for the novae or supernovae.

As usual, the speaker by his excellent analogies and casual humor gave added interest to this timely subject.

HENRY F. DONNER.

Western Reserve University, Cleveland 6, Ohio.

Fifth Nation-Wide Science Talent Search Scheduled

The fifth annual Science Talent Search—but the first in peacetime—among America's million high school seniors to discover the 40 students with the greatest scientific potential was begun in September in the nation's 27,000 high schools. Entrants will compete for $11,000 in Westinghouse Science Scholarships.

This nation-wide quest for scientifically-talented students is open to all high school seniors or their equivalent in American public, private or denominational schools, Mr. Davis explained.

The Search is sponsored by the Westinghouse Electric Corporation with the scholarships provided by the Westinghouse Educational Foundation in the interests of the advancement of science in America. It is conducted by Science Clubs of America, through Science Service.

Two four-year Westinghouse Science Grand Scholarships of $2,400 each will be granted to the top boy and girl, and eight four-year Westinghouse Science Scholarships of $400 each will be awarded during the Institute following final tests and interviews by the board of judges. An additional $3,000 may be distributed at the discretion of the judges.

The primary objective of the Science Talent Search are: 1. To discover and foster the education of boys and girls whose scientific skill, talent, and ability indicate potential creative originality and warrant scholarships for their development. 2. To focus the attention of large numbers of scientifically gifted youths on the need for perfecting scientific and research skill and knowledge so that they can increase their capacities for contributing to the rehabilitation of a war-dislocated world and to help the United States, with the aid of science, to lead the world to permanent peace. 3. To help make the American public aware of the varied and vital rôle science plays in world affairs and in raising the standard of living.